Section One: Short answers (54 Marks)

This section has **fourteen (14)** questions. Answer **all** questions. Write your answers in the spaces provided.

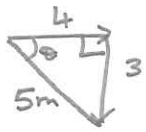
Suggested working time: 54 minutes.

Question 1 (3 marks)

A child playing mini golf puts the ball 4 m east, then 3 m south sinking the ball in the hole in two puts. State the distance covered by the ball and the ball's displacement.

Distance covered = 7m [1 mark]

Displacement = 5m (1) East 36.9° South (1) [2 marks]



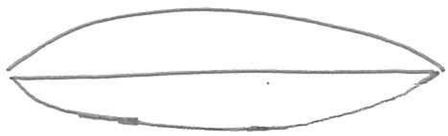
$\tan\theta = \frac{3}{4}$

$\theta = 36.9°$

Question 2 (3 marks)

A violin string is tuned to a fundamental frequency of 500 Hz.

(a) Sketch below to show the fundamental and the second harmonic of the violin string. (2 marks)



fundamental

2nd harmonic

(b) If the violin string has a length of 32 cm, what is the wavelength of the fundamental? (1 mark)

$L = 0.32 \text{ m}$

$\lambda = 2L$

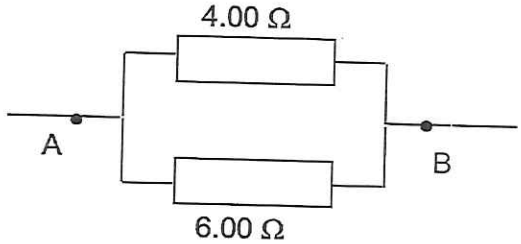
$= 2 \times 0.32$

$= 0.64 \text{ m}$

Question 3

(4 marks)

Two resistors are connected as shown in the diagram at right. A potential difference of 12.0 V is applied between points A and B.



(a) State the voltage drop across each resistor.

4.00 Ω resistor: 12·0V

6.00 Ω resistor: 12·0V

(b) Give the current flowing through each of the resistors.

4.00 Ω resistor: 3·00A

6.00 Ω resistor: 2·00A

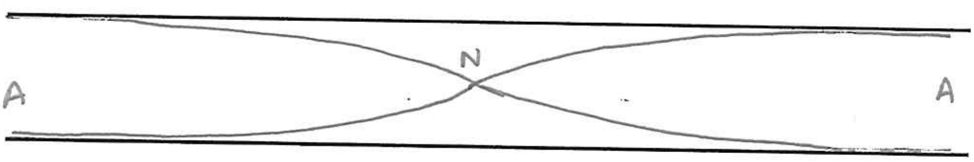
Question 4

(5 marks)

A flute can be treated as a resonant pipe open at both ends with a length of 55 cm. The fundamental frequency of this flute is 312 Hz at 20°C.

(a) Draw the standing wave (displacement-distance envelope) produced when the flute is played so that the **fundamental** frequency is heard. Label each node and antinode. (2 marks)

(1) sketch
(½) node
(½) antinode



(b) By how much does the fundamental frequency change when the temperature of the room increases by 5°C? (Assume that the length of the flute itself does not change significantly as the room temperature increases.) (3 marks)

At 20°C

$\lambda = 2 \times 0{\cdot}55$

$= 1{\cdot}10\,m$ (1)

$f = 312\,Hz$

$\Delta f = 314{\cdot}55 - 312$

$= 2{\cdot}55\,Hz$ (1)

At 25°C $v = 346\,ms^{-1}$

$\lambda = 1{\cdot}10\,m$

$f = \frac{v}{\lambda}$

$= \frac{346}{1{\cdot}10}$

$= 314{\cdot}55\,Hz$ (1)

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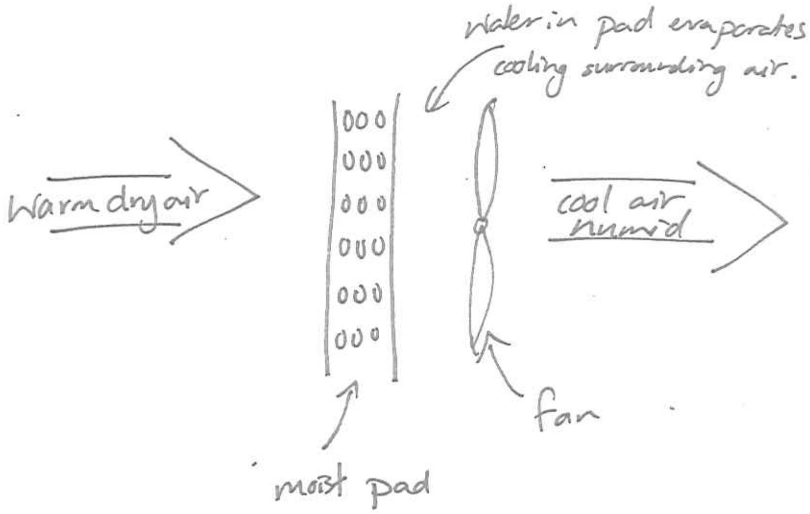
Question 5 **(3 marks)**

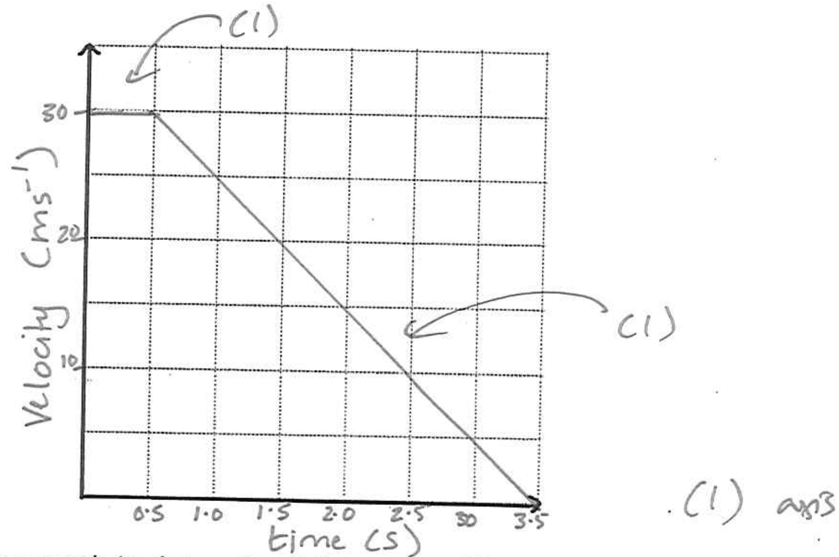
Draw a simple, clear, well labelled diagram to explain the operation of an evaporative air conditioner.



Question 6 **(5 marks)**

A car is travelling along a road at 30 ms^{-1} when a pedestrian steps onto the road 55m ahead. The driver see the pedestrian and applies the brakes of the car after a reaction time of 0.5s. The car slows down at a constant rate of 10 ms^{-2} until it comes to rest.

(a) Draw a graph of velocity vs time on the axes below to show the motion of the car. (3 marks)



(b) Use your graph to determine if the car would strike the pedestrian. (2 marks)

Area under curve = displacement

$s = 30 \times 0{\cdot}5 + \frac{30 \times 3}{2} = 60\text{m}$ (1)

Yes, car would hit the pedestrian as 60m stopping distance > 55m. (1)

Question 7 **(4 marks)**

One method of producing plutonium-238 is by bombarding uranium-238 with deuterium (hydrogen-2), to produce neptunium-238 and two neutrons. The unstable neptunium-238 then decays to produce plutonium-238. Write the nuclear equations for these two reactions, showing all particles involved in each reaction.

$$^{238}_{92}U + ^{2}_{1}H \rightarrow ^{238}_{93}Np + 2\,^{1}_{0}n$$

($-\frac{1}{2}$) for each error.

$$^{238}_{93}Np \rightarrow ^{238}_{94}Pu + ^{0}_{-1}e$$

Question 8 **(4 marks)**

Protective clothing is used by workers around the world to help keep them safe. In terms of heat transfer, explain how each of the following helps keep the wearer safe:

(a) Smelting workers wear aluminumized jackets and gloves. (2 marks)

The silvered Al jacket + gloves are effective at reflecting the infrared (1) radiation being emitted from the smelting pot.

∴ Less heat is absorbed as it is reflected by the jacket + gloves. (1)

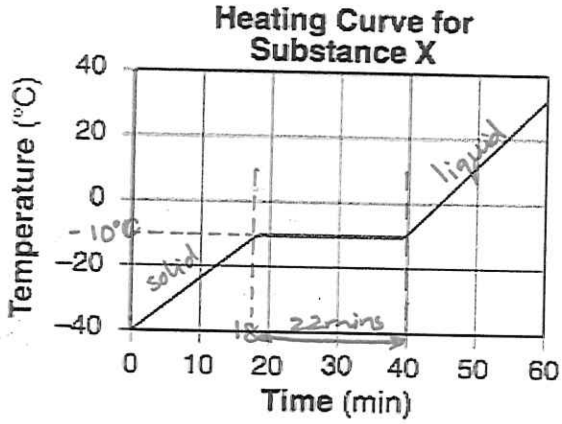
(b) Arctic Sea Rescue workers wear a layer underneath their outer jackets which consists of a three-dimensional knitted material, with wool on the inside and outside and a mesh that maintains gaps between these layers. (2 marks)

The wool + the air pockets in the 3D knit are poor conductors (1) of heat preventing heat being lost to the surroundings.

∴ trapping a layer of warm air close to the wearers body. (1)

Question 9 (5 marks)

The graph at right shows how the temperature of 1.00 kg of substance X varies as it is steadily heated by a 50.0 W element. Substance X is initially in the solid phase. From the graph, determine substance X's



(a) melting point. (1 mark)

$-10°C$

(b) latent heat of fusion. (2 marks)

$m = 1.0\ kg$

$P = 50\ W = 50\ Js^{-1}$

time to melt = 22 mins (½)

$Q = 22 \times 60 \times 50 = 66{,}000\ J$ (1)

$Q = mL_f$

$L_f = \frac{66{,}000}{1.0} = 66.0\ kJ\,kg^{-1}$ (½)

(c) specific heat when in the liquid phase. (2 marks)

$\Delta T = 40°C$ (½)

$m = 1.0\ kg$

time for ΔT = 20 mins

$Q = 20 \times 60 \times 50 = 60{,}000\ J$ (½)

$Q = mc_x\Delta T$

$c_x = \frac{Q}{m\Delta T} = \frac{60{,}000}{1.0 \times 40} = 1.50\ kJ\,kg^{-1}K^{-1}$ (1)

Question 10 (4 marks)

Indicate whether each of the following statements is true (T) or false (F).

(a) When a gas is compressed its temperature rises. T

(b) It is not possible to cool a substance below 0 K T

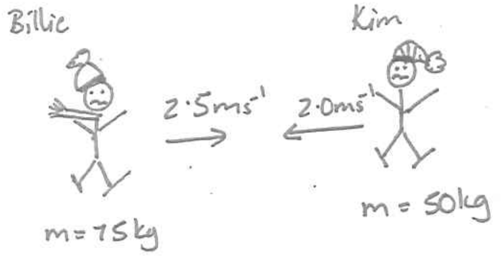
(c) An voltmeter should be connected in series. F

(d) Gamma rays have a very high ionising ability. F

Question 11 **(3 marks)**

Kim is a 50 kg ice skater who travels left at 2.0 m s^{-1} towards Billie. Billie has a mass of 75 kg and travelling right at 2.5 m s^{-1}. They collide, hold onto each other, and move off together. What is their velocity after the collision?

right is +ve.



$\Sigma p_{before} = \Sigma p_{after}$ (1)

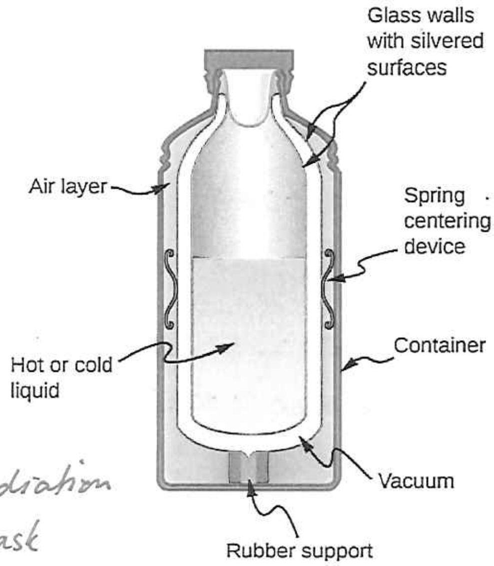
$m_B u_B + m_K u_K = m_{B+K} v$

$75 \times 2.5 + 50 \times -2.0 = (75+50) v$ (1)

$v = 0.7 \text{ ms}^{-1}$ ($\frac{1}{2}$) right ($\frac{1}{2}$)

Question 12 **(3 marks)**

The diagram at right shows a cross-section of a vacuum (Thermos) flask, which is designed to store hot liquids with minimal loss of heat over time. Briefly explain how its design reduces heat loss from a stored hot liquid, with reference to all three heat transfer processes.



stopper – traps warm air above liquid in flask + prevents heat loss via convection (1)

glass walls with silvered surface – reflect infrared radiation back into contents of flask & preventing heat loss via radiation (1)

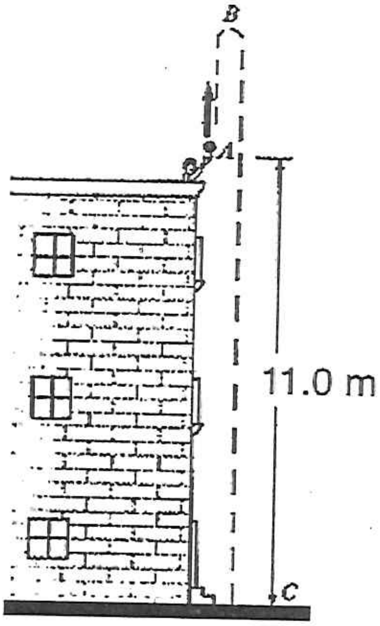
air layer – good insulator and prevents heat loss via conduction (1)

vacuum – no particles present ∴ prevents heat transfer via conduction

} either or both.

Question 13 **(4 marks)**

A woman throws a tennis ball vertically up into the air from a building rooftop. She releases the ball at point A at a speed of 10 ms^{-1}.



(a) What maximum height above the ground does the ball reach? (2 marks)

$u = 10 ms^{-1}$ $\quad v^2 = u^2 + 2as$

$a = -9.8 ms^{-2}$ $\quad 0 = 10^2 + 2 \times -9.8 \times s$

$v = 0 ms^{-1}$ $\quad s = \frac{-100}{-19.6}$ $= 5.10$ m (1)

∴ Height above ground $= 11.0 + 5.10 = 16.1$ m. (1)

(b) At what velocity will the tennis ball strike the pavement? (ignore the effects of air resistance) (2 marks)

$s = 16.1$ m $\quad v^2 = u^2 + 2as$

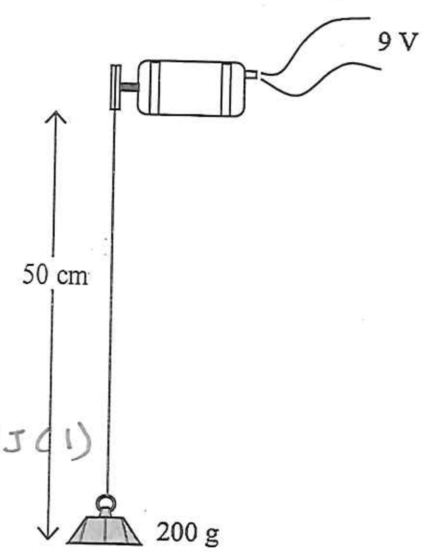
$a = 9.8 ms^{-2}$ $\quad = 0^2 + 2 \times 9.8 \times 16.1$ (1)

$u = 0 ms^{-1}$ $\quad v = \sqrt{315.56}$

$= 17.8 ms^{-1}$ ($\frac{1}{2}$) down ($\frac{1}{2}$)

Question 14 **(4 marks)**

A small electric motor is connected to a 9.00 volt battery. The motor is switched on and takes 2.0 s to lift a 200 g mass upwards through 50.0 cm.



(a) What useful work is done by the motor? (2 marks)

$W = \Delta E_p$ (1)
$= mgh$
$= 0.2 \times 9.8 \times 0.5$
$= 0.98$ J. (1)

(b) If the motor is 80% efficient what current will the motor draw from the battery as it operates? (2 marks)

$t = 2.0$ s
$V = 9.00$ V

If 80% efficient $E_{total} = \frac{0.98}{0.8} = 1.225$ J (1)

$P = \frac{E}{t} = \frac{1.225}{2} = 0.6125$ W

$P = VI \quad I = \frac{P}{V} = \frac{0.6125}{9.00} = 0.07$ A (1)

END OF SECTION ONE

See next page

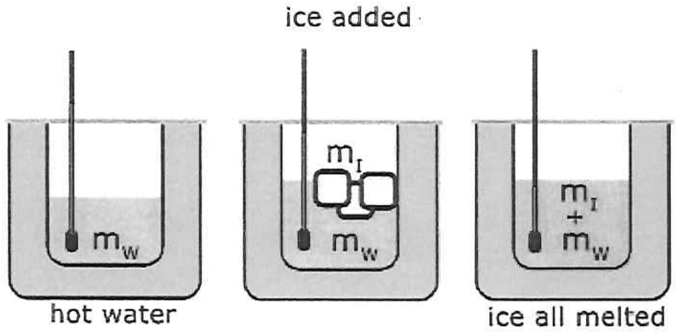
Section Two: Problem Solving (90 Marks)

This section has **six (6)** questions. Answer **all** questions. Write your answers in the spaces provided.

Suggested working time: 90 minutes.

Question 15 (14 marks)

A Physics student conducted an experiment to determine the latent heat of ice using a copper calorimeter packed in a foam container, similar to the apparatus in the diagram at right.



Ice was dried with paper towel and added to the hot water in the calorimeter and stirred continually until a significant temperature drop was recorded.

The mass of the calorimeter and contents was then re-measured.

The student tabulated the following results:

Initial temperature of ice (°C)	0	±0.5 °C
Mass of empty copper calorimeter (g)	80.00	±0.05g
Mass of hot water and copper calorimeter before adding the ice (g)	180.00	±0.05g
Initial temperature of hot water and calorimeter(°C)	50	±0.5 °C
Mass of water calorimeter and ice after ice melts (g) ammended!	235.00	±0.05g
Final temperature of calorimeter and water after adding the ice (°C)	10	±0.5 °C
Mass of ice added to calorimeter (g)	55.00g	

(a) Calculate the mass of ice added to the calorimeter and record this in the table above. (1 mark)

235 - 180 = 55.0g

(b) Calculate the percentage uncertainty of the mass of ice. (2 marks)

55.0g ± 0.10g (1)

55.0g ± 0.18% (1)

(c) Why was the calorimeter packed in a foam container? (2 marks)

(1)
Foam is a good insulator as it is a poor conductor of heat

∴ Packing in foam prevents heat loss to the surroundings via conduction (1)

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(d) Using the student's data calculate the latent heat of fusion of ice. Show all working. Use the specific heat capacity of copper as 385 $Jkg^{-1}K^{-1}$. (5 marks)

$c_{Cu} = 385\ Jkg^{-1}k^{-1}$

$m_{ice} = 0.055\ kg$

$m_{Cu} = 0.08\ kg$

$\Delta T_{Cu} = 40\ °C$

$m_{hot\ H_2O} = 0.100\ kg$

Heat lost by calorimeter + hot water = Heat gained by ice (1)

$m_{Cu} c_{Cu} \Delta T_{Cu} + m_{hot\ H_2O} c_W \Delta T_{hot\ H_2O} = m_{ice} L_{f_{ice}} + m_{ice} c_W \Delta T_{ice}$ (1)

$0.08 \times 385 \times 40 + 0.1 \times 4180 \times 40 = 0.055 \times L_{f_{ice}} + 0.055 \times 4180 \times 10$ (1)

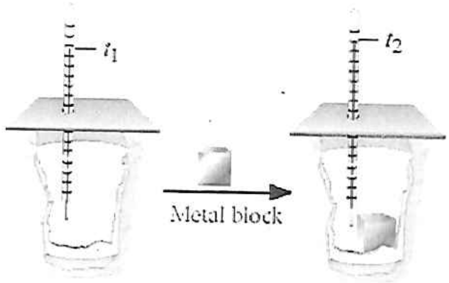
$1232 + 16{,}720 = 0.055 \times L_{f_{ice}} + 2{,}299$ (1)

$L_{f_{ice}} = \dfrac{17{,}952 - 2{,}299}{0.055}$

$= 2.85 \times 10^5\ J\,kg^{-1}$ (1)

(e) The student then conducts another test to find the specific heat of an unknown metal.

They left a 57.9 gram block of the metal in a beaker of boiling water for several minutes and then quickly transferred it to an insulated cup containing 60 mL of water at a temperature of 22.0°C. The temperature reached by the water and metal block once thermal equilibrium has been achieved is 28.5°C.



Assuming that heat transfer only occurs between the metal and the water in the cup, calculate the specific heat of the metal. (4 marks)

Heat gained by water = heat lost by metal block

$m_W c_W \Delta T = m_x c_x \Delta T_x$ (1)

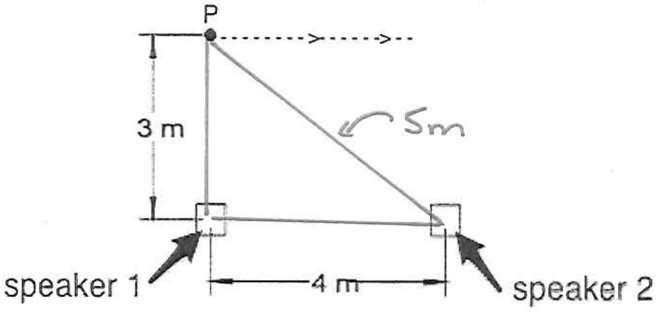
$0.06 \times 4180 \times (28.5 - 22)$ (1) $= 0.0579 \times c_x$ (1) $(100 - 28.5)$

$c_x = \dfrac{1{,}630.2}{4.14}$

$= 3.94 \times 10^2\ J\,kg^{-1}k^{-1}$ (1)

Question 16 **(14 marks)**

Two speakers are placed on the floor 4 metres apart, as shown in the diagram at right, on a day when the room temperature is 25°C. You stand at point P, which is 3 metres directly in front of one of the speakers. The speakers are both connected to an audio frequency generator which is producing a steady 518 Hz note.



(a) Demonstrate through calculations whether you will hear a loud or a soft sound when standing at point P. (4 marks)

$PD = 5 - 3$
$= 2\,m$ (1)

$\frac{PD}{\lambda} = \frac{2}{0.668}$
$= 2.99$

$\lambda = \frac{v}{f}$
$= \frac{346}{518}$
$= 0.668\,m$ (1)

PD whole nº multiple of λ ∴ constructive (1) interference

constructive interference results in loud sound (1)

(b) Describe what you would hear if you were to walk slowly along the dotted line shown above, moving to the right away from point P, and explain why. (3 marks)

You would hear a series of alternating loud and quiet sounds as you walk along the dotted line away from P. (1)

The PD changes as you walk along the line. resulting in areas of constructive interference – loud sounds (1) as the wave arrive in phase. and destructive interference – quiet sounds (1) as the waves arrive out of phase.

(c) The limits of audible hearing for a young, healthy person such as yourself are usually given as 20Hz - 20kHz. What is the lowest frequency that could be produced by the speakers in order for you to hear a loud sound at Point P? (3 marks)

lowest frequency when wavelength = PD = 2m (1)

$\lambda = 2m$

$v = 346 ms^{-1}$

$f = \frac{v}{\lambda}$ (1)

$= \frac{346}{2} = 173 Hz$. (1)

(d) The speakers are now re-connected to the audio frequency generator so that speaker 1 produces 460 Hz and speaker 2 produces 464 Hz. They are then played simultaneously.

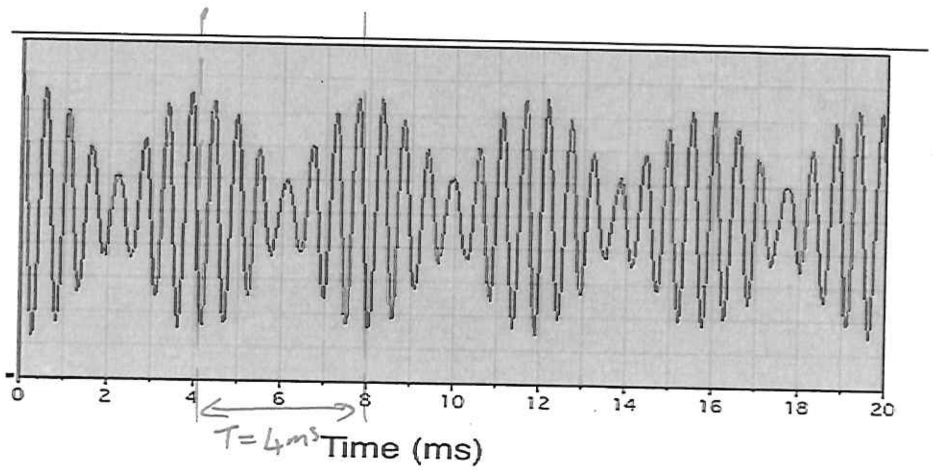
(i) What average frequency will you hear? (1 mark)

$f_{average} = \frac{460+464}{2} = 462 Hz$ (1)

(ii) What is the resultant beat frequency? (1 mark)

$f_{beat} = |f_2 - f_1| = 464 - 460 = 4 Hz$ (1)

(e) The graph below shows the CRO trace for a London Police officer's whistle. The whistle is designed so that it uses two short pipes blown at once to produce a unique piercing sound. Use the graph to determine the frequency of the beats produced by the whistle. (2 marks)



$T = 4 ms$ (1)

$f = \frac{1}{T}$

$= \frac{1}{4 \times 10^{-3}}$

$= 250 Hz$ (1)

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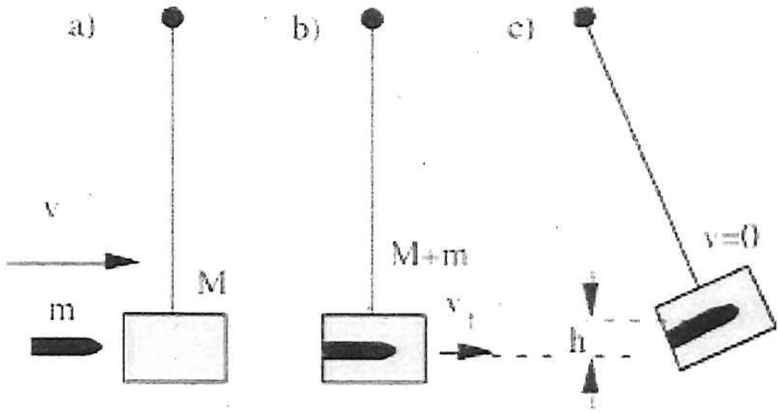
Question 17 **(19 marks)**

A ballistic pendulum is a device that can be used by forensic scientists to determine the speed of a bullet.

The pendulum consists of a large wooden block hanging vertically, as shown in diagram a) at right, at which a bullet is fired horizontally.



The bullet hits the wooden block and remains embedded in it, transferring most of its momentum to the block (diagram b).

The speed of the system after collision can be determined by measuring the maximum height to which the block swings (diagram c).

The mass of the bullet is 10.0 g and the mass of the block is 2.30 kg.

(a) The block (plus embedded bullet) swings upwards to a maximum height of 26.0 cm. Calculate their increase in gravitational potential energy. (2 marks)

$\Delta E_{gp} = mg\Delta h$ ①

$= (2.30 + 0.01) \times 9.8 \times 0.26 \text{ m}$

$= 5.89 \text{ J}$ ①

(b) Determine the initial speed of the block as it first begins to swing upwards, immediately after the bullet is embedded in it. (3 marks)

$\Delta E_k = \Delta E_{gp}$ ①

$\frac{1}{2}mv^2 = 5.89$

$\therefore v = \sqrt{\frac{2 \times 5.89}{2.31}}$ ①

$= 2.26 \text{ ms}^{-1}$ ①

(c) Calculate the momentum of the block plus embedded bullet immediately after the bullet strikes the block (diagram b). (2 marks)

$p_{after} = mv$ ①
$= 2.31 \times 2.26$
$= 5.21 \text{ kg m s}^{-1}$ ①

(d) Hence, calculate the speed of the bullet before hitting the block. (2 marks)

$p_{before} = p_{after}$ ①
$\therefore m_b u_b = (m_B + m_b) v_{B+b}$
$\therefore u_b = \frac{5.21}{0.01} = 521 \text{ m s}^{-1}$ ①

(e) Determine the kinetic energy of the bullet before collision, and compare it to the kinetic energy of the block plus bullet after collision. (3 marks)

$E_k \text{ before} = \frac{1}{2} m_b u_b^2$
$= \frac{1}{2} \times 0.01 \times 521^2$
$= 1{,}360 \text{ J}$ ①

$E_k \text{ after} = \frac{1}{2}(m_B + m_b) v_{B+b}$
$= \frac{1}{2} \times 2.31 \times 2.26^2$
$= 5.90 \text{ J}$ ①

$\therefore$ Ek after is much less than before only $\frac{6}{1360} \times 100\% = 0.4\%$ remains ①

(f) Is this collision elastic? Justify your answer. (2 marks)

The collision is not elastic ① as almost all the energy has been converted to heat. ① (99.6% lost)

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(g) An identical bullet is now fired from the same gun under the same conditions except now the block is fixed in position so that the bullet imbeds in the block and comes to a complete stop. The temperature of the bullet immediately before it stikes the target is 20°C. Assuming that 85% of the heat generated is absorbed by the bullet, will the bullet melt completely? Justify your answer by showing your calculations. (5 marks)

Physical data for lead

Melting point	328 °C
Boiling point	1749 °C
Latent heat of fusion	22.4×10^3 Jkg^{-1}
Specific heat capacity	164 $Jkg^{-1}K^{-1}$

$Q = 0.85 \, E_k$ before ①

$= 0.85 \times 1360$ J

$= 1156$ J ①

$Q_{melt} = mc\Delta T_{Pb} + mL_{Pb}$ ①

$= 0.01 \times 164 \times (328 - 20) + 0.01 \times 22.4 \times 10^3$

$= 505 + 224$

$= 729$ J ①

∴ Yes the bullet melts completely as there is more than enough energy available. ①

Question 18 **(18 marks)**

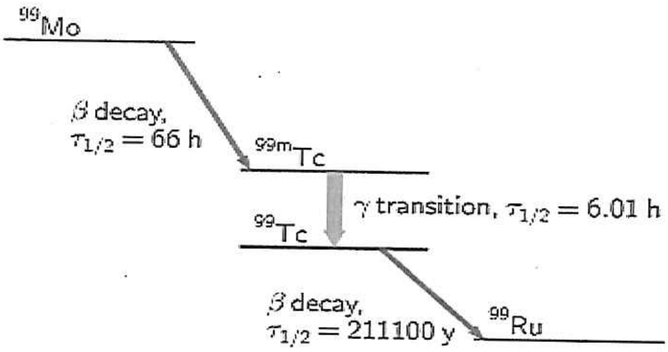
Technetium-99m is a nuclear isomer of technetium-99. It is the most common medical radioisotope in use today. Technetium-99m is produced by bombarding Molybdenum-98 with neutrons. Molybdenum-99 is then produced. This then undergoes a beta decay with a half life of 66 hours to produce Technetium-99.

(a) Write two balanced nuclear equations to show the production of Mo-99 from Mo-98 and the subsequent decay of Mo-99 into Tc-99. (2 marks)

$$^{1}_{0}n + ^{98}_{42}Mo \rightarrow ^{99}_{42}Mo \quad ①$$

$$^{99}_{42}Mo \rightarrow ^{99}_{43}Tc + ^{0}_{-1}e \quad ①$$

Technetium-99 isn't stable and finally ends up, following another Beta decay, as Ruthenium-99 as in the diagram below.



(b) Technetium-99m emits gamma rays with energy of 140 keV. How many joules of energy are emitted with each gamma decay? (1 mark)

$$E = 140\,keV = 140 \times 10^{3} \times 1.6 \times 10^{-19}\,J$$

$$= 2.24 \times 10^{-14}\,J \quad ①$$

(c) Technetium-99 emits both β^- and γ radiation.

(i) Which of these is a form of electromagnetic radiation? (1 mark)

γ radiation ①

(ii) Which of these radiation types would be useful for bone scan detection by a special camera outside the body? Explain your answer (2 marks)

γ radiation ① as it will pass through the body ① and cause only moderate ionisation.

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Technetium generators, which contain the radioisotope, are supplied to Australian hospitals from the Lucas Height nuclear reactor where the Mo-99 radioisotope is artificially produced. They contain Mo-99, with a half-life of 66 hours, which progressively decays to Tc-99. When delivered to Australian hospitals the Technetium generators have an activity of 100 GBq due to the Mo-99 radioisotope.

(d) What does the phrase "a half-life of 66 hours" mean? (1 mark)

It means that half of the parent nucleus (Mo-99) will decay into the daughter product (Tc-99) in 66 hours. ①

(e) Calculate the number of days taken for the activity of the Mo-99 radioisotope in a Technetium generator to drop to only 1.0 GBq. (4 marks)

$N_0 = 100\ GBq$
$N = 1.0\ GBq$
$T_{\frac{1}{2}} = 66\ h$

$N = N_0\left(\frac{1}{2}\right)^n$ ①

$\therefore \frac{N}{N_0} = \left(\frac{1}{2}\right)^n$

$\therefore \log(N/N_0) = n \log\left(\frac{1}{2}\right)$

$\therefore n = \log(N/N_0) / \log\left(\frac{1}{2}\right)$

$= \log(0.01) / \log(0.5)$

$= 6.64$ ①

$n = t/T_{\frac{1}{2}} \quad \therefore t = n T_{\frac{1}{2}} = 6.64 \times 66\ h$ ①

$= 438\ h = 18.3\ days$ ①

(f) In 2017 a 65 kg radiation worker in the Lucas Heights reactor spilt a vial of Mo-99 while preparing a Technetium generator. She was exposed to 1300 J of radiation.

(i) What was her absorbed dose ? (2 marks)

$A.D = \frac{Energy}{Mass} = \frac{1300 J}{65 kg} = 20\ Gy$ ① ①

(−½ units)

(ii) What was the dose equivalent? (2 marks)

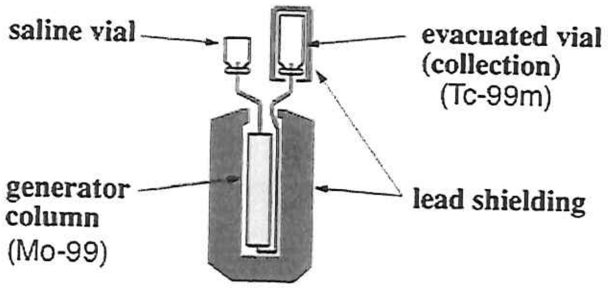
$D.E = A.D \times Q.F.$

$QF = 1$ (β decay) ①

$\therefore D.E = 20 \times 1 = 20\ Sv$ ① (−½ units)

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT

The technetium generators consist of a saline vial that is squeezed through a column of Mo-99 in order to collect Tc-99m, as shown in the diagram below.



(g) Describe the function of the lead shielding around the generator column. (1 mark)

The lead shielding is required to prevent a large portion of the gamma radiation from entering the surroundings
①

(h) The radiographer and other nuclear medicine workers wear a TLD (a thermoluminescent dosimeter) or film badge. Explain why it is necessary to wear such a device. (2 marks)

The badges will detect exposure to radiation over a prolonged period of time, as ①
the total dose of radiation will determine the risk of cancer development. ① Thus workers can limit their yearly exposure to a safe dose.

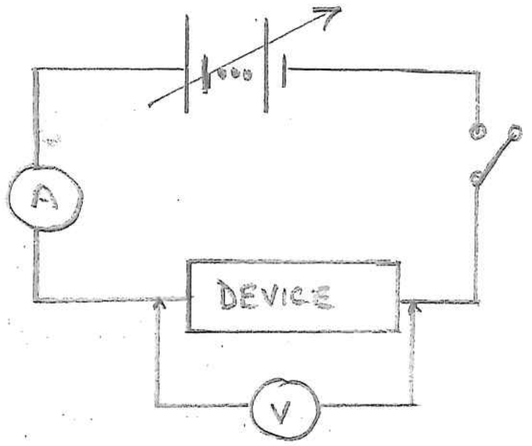
Question 19 **(13 marks)**

A Year 11 Physics student carried out an experiment that measured the current through and voltage across a particular circuit device, identified only as Device A, as the voltage across it was successively increased. She then replaced the device and repeated the experiment for a second circuit device, identified as Device B. The tables below show the data she recorded during the experiment.

Device A	
Current (A)	Voltage (V)
0.00	0.00
0.93	0.99
1.23	2.00
1.49	2.93
1.68	3.76
1.99	5.20
2.12	5.82
2.24	6.41
2.32	6.94

Device B	
Current (A)	Voltage (V)
0.00	0.00
0.13	1.37
0.26	2.66
0.40	3.94
0.51	5.05
0.63	6.23
0.73	7.19
0.84	8.26
0.95	9.25

(a) Draw a diagram of a possible circuit that could have been used to collect this data for either device. (3 marks)

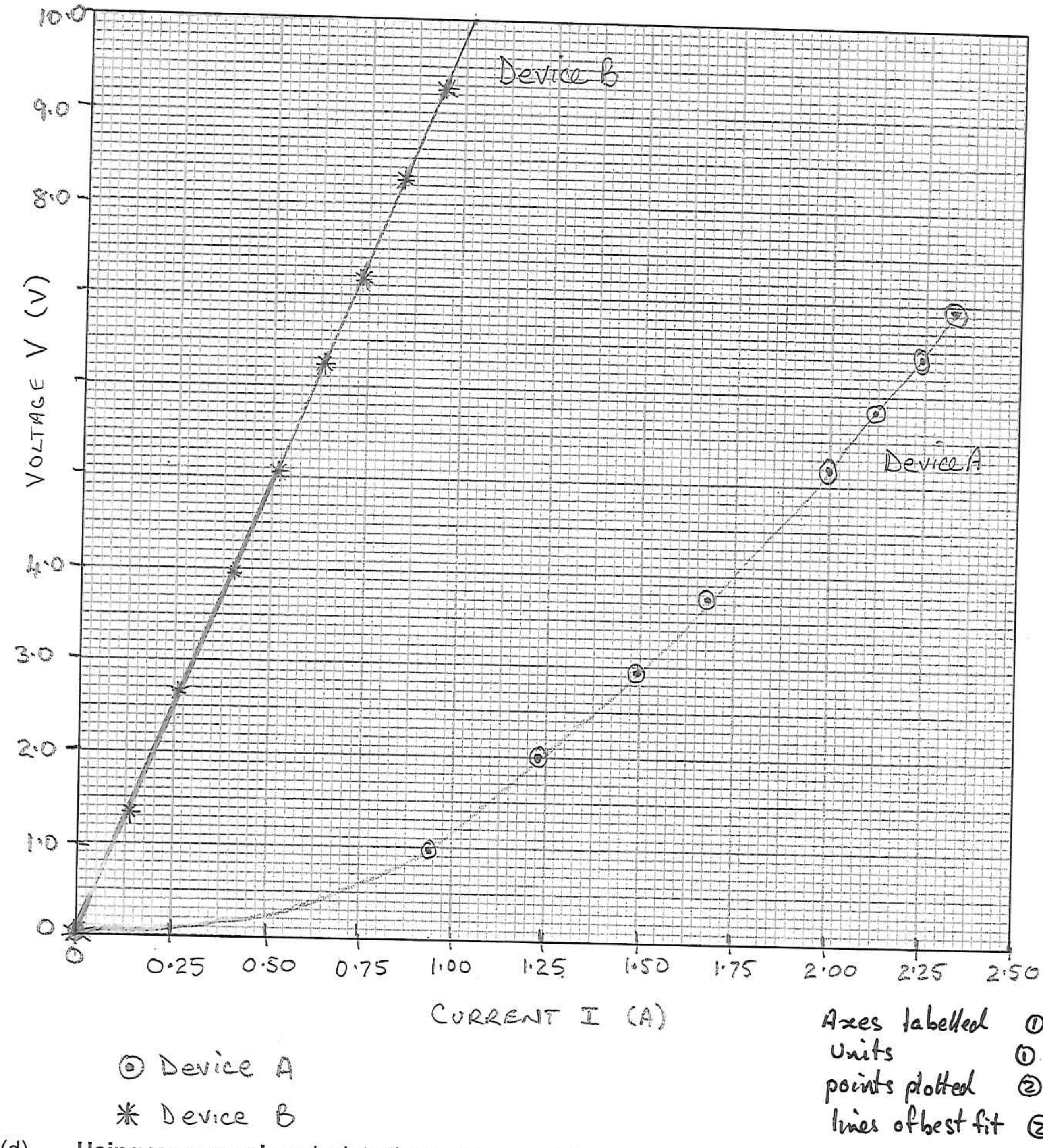


① Ammeter in series
① Voltmeter in parallel
① battery, switch and variable supply or rheostat.

(b) On the graph paper on the next page, draw a graph of voltage versus current for both Device A and Device B using the same set of axes. (6 marks)

(c) Which of the two components is a **non-ohmic** conductor? Justify your answer. (2 marks)

① Device A is non-ohmic as it does not form a linear pattern for V vs I. ie. Current is not proportional to applied voltage. ①



Axes labelled ①
Units ①
points plotted ②
lines of best fit ②

(d) **Using your graph**, calculate the resistance of the component which is an **ohmic** conductor.

(2 marks)

Device B: $R = \frac{10.0}{1.025} = 9.8\ \Omega$ ①

Values from graph ①

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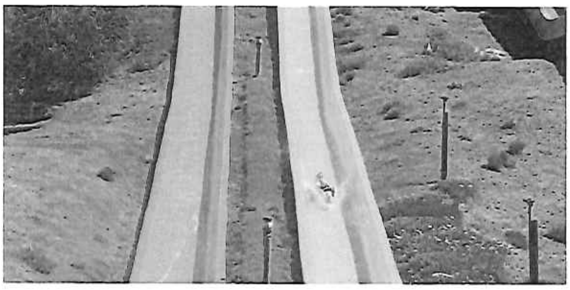
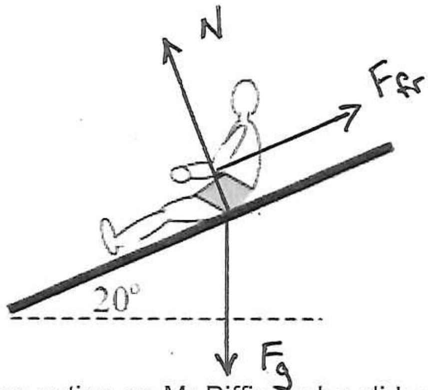
Question 20 **(12 marks)**

Mr Biffin hurtles down the Wahoo speed slide at Adventure World yelling "I love Physics!!" all the way down. He starts from rest at the top of the slide and reaches a top speed of 66 km/h. At the start of the slide Mr Biffin rides at an angle of 20° to the horizontal.





(a) On the diagram (above right) show all the forces acting on Mr Biffin as he slides. (3 marks)

−1 extra forces ① each

(b) Why does the Wahoo Speed Slide need to have water on it? Explain (2 marks)

The water is needed to reduce friction as this force would retard motion too much and also lead to friction burns.

(c) Mr Biffin reaches his top speed after travelling for 8.0 seconds down a 70 m length of the slide angled at 20° to the horizontal. How much work was done by the force of friction? (Mrs Caporn generously estimates Mr Biffin's mass to be 90 kg) (5 marks)

$v = 66 \text{ km/h} = 18.3 \text{ m s}^{-1}$ ①
$u = 0 \text{ m s}^{-1}$
$t = 8.0 \text{ s}$
$s = 70.0 \text{ m}$
$\theta = 20°$

$\Delta h = s\sin\theta = 70 \sin 20° = 23.9 \text{ m}$ ①

$\Delta E_{gp} = \Delta E_K + W_{fr}$ ①

$\therefore W_{fr} = \Delta E_g - \Delta E_K$
$= mg\Delta h - \frac{1}{2}mv^2 \quad (u=0)$ ①
$= 90 \times 9.8 \times 23.9 - \frac{1}{2} \times 90 \times (18.3)^2$
$= 2.11 \times 10^4 - 1.51 \times 10^4$
$= 5.99 \times 10^3 \text{ J}$ ①

(d) Mr Biffin wishes to slide even faster. Write 2 suggestions below to assist him achieve this goal and briefly explain your reasoning for each. (2 marks)

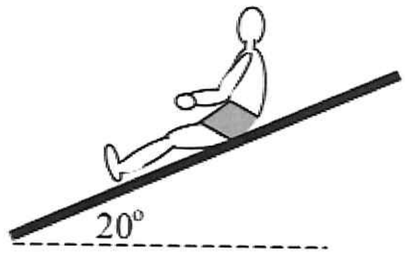
(i) Carry some extra mass. ① The F_{fr} is due to water and air resistance which do not depend on mass but the force down does. ①

(ii) Get into a streamlined position. This reduces the friction force due to air resistance. (also allow streamlined suit)

END OF SECTION TWO

Question 20 **(12 marks)**

Mr Biffin hurtles down the Wahoo speed slide at Adventure World yelling "I love Physics!!" all the way down. He starts from rest at the top of the slide and reaches a top speed of 66 km/h. At the start of the slide Mr Biffin rides at an angle of 20° to the horizontal.



(a) On the diagram (above right) show all the forces acting on Mr Biffin as he slides. (3 marks)

(b) Why does the Wahoo Speed Slide need to have water on it? Explain (2 marks)

(c) Mr Biffin reaches his top speed after travelling for 8.0 seconds down a 70 m length of the slide angled at 20° to the horizontal. How much work was done by the force of friction? (Mrs Caporn generously estimates Mr Biffin's mass to be 90 kg) (5 marks)

Alternate solution using time and forces (time given inconsistent!) should be 7.6 s

$v = 66\ km/h = 18.3\ m/s$

$a = \frac{v-u}{t} = \frac{18.3-0}{8} = 2.29\ m/s^2$

$F_{net} = ma = 90 \times 2.29 = 206\ N$

$F_{g\parallel} = mg\sin\theta = 90 \times 9.8 \times \sin 20° = 302\ N$

$F_{net} = F_{g\parallel} - F_{fr} \therefore F_{fr} = F_{g\parallel} - F_{net} = 302 - 206 = 95.6\ N$

$W_{fr} = F_{fr} \times s = 95.6 \times 70 = 6690\ J$

(d) Mr Biffin wishes to slide even faster. Write 2 suggestions below to assist him achieve this goal and briefly explain your reasoning for each. (2 marks)

END OF SECTION TWO

Section Three: Comprehension

(36 Marks)

This section has **two (2)** questions. Write your answers in the spaces provided.

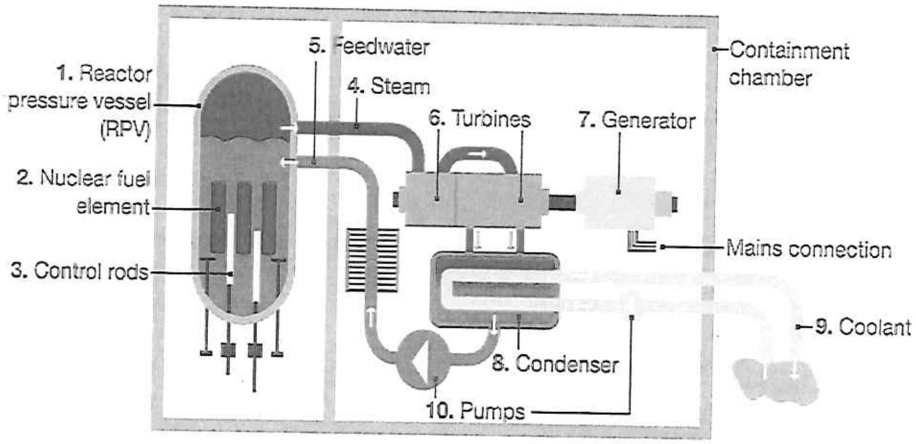
Suggested working time: 36 minutes.

Question 21 **FUKUSHIMA NUCLEAR DISASTER** **(18 marks)**

(Paragraph 1)

Nuclear reactors generate electricity by using the heat of the fission reaction to produce steam, which is used to drive turbines to generate electricity. The diagram at right shows a Boiling Water Reactor (BWR), which were the design used at the Fukushima nuclear power plant in Japan. The Fukushima nuclear disaster was initiated primarily by the tsunami which followed an earthquake on 11 March 2011. Immediately after the earthquake, the active reactors automatically shut down their sustained fission reactions by inserting control rods in a safety procedure referred to as SCRAM, which ceases the reactors' normal running conditions.

Boiling Water Reactor system



Source: RobbyBer/Wikimedia

(Paragraph 2)

When the reactor stops operating, the radioactive decay of unstable isotopes in the fuel continues to generate heat (decay heat) for a time, and so require continued cooling. Initially this decay heat amounts to approximately 6.5% of the amount produced by fission, decreasing over several days before reaching shutdown levels.

(Paragraph 3)

When the reactors were shutdown, they were unable to generate power to run their own coolant pumps, so emergency diesel generators came online, as designed, to power the coolant systems. However, the tsunami, which hit 50 minutes after the initial earthquake, overwhelmed the nuclear plant's seawall and flooded the low-lying rooms in which these emergency generators were housed, causing them to fail soon afterwards, and resulting in a loss of power to the critical coolant water pumps. These pumps were needed to continuously circulate coolant water through the reactor core to keep the fuel rods from melting. The insufficient cooling eventually led to meltdowns in the cores of Reactors 1, 2, and 3. The full extent of the movement of the resulting **corium** is unknown but it is now considered to be at least through the bottom of each reactor pressure vessel (RPV), residing somewhere between there and the water-table below each reactor.

(Paragraph 4)

After being used in the reactor core, spent fuel rods typically require several years in a spent fuel pool before they can be safely transferred to dry storage vessels. Loss of cooling after the tsunami also caused the spent fuel pool to overheat due to decay heat; the decay heat in the spent fuel pool had the capacity to boil about 70 tonnes of water per day.

(a) Draw an energy flow diagram to show the sequence of energy transformations in a Boiling Water Reactor (BWR) that leads to the generation of electricity. (paragraph 1) (2 marks)

nuclear energy → heat (thermal) energy → kinetic energy → electrical energy

($\frac{1}{2}$) mark each in correct sequence.

(b) Describe the safety procedure referred to as SCRAM. (paragraph 1) (2 marks)

($-\frac{1}{2}$) if automatically not included.

The control rods were automatically inserted (1) into the core of the reactors causing the nuclear fission reactions to shut down (1)

(c) Explain how heat continues to be produced in a reactor core after the reactor stops operating. (paragraph 2) (2 marks)

After the fission reaction stops continued radioactive decay (1) of the unstable isotopes (1) in the fuel produces heat.

(d) Outline the sequence of events, after the earthquake and tsunami hit the nuclear power plant, that eventually led to meltdowns in the reactor cores. (paragraph 3) (4 marks)

reactors were automatically shut down + were unable to power the water coolant pumps (1)

back up generators located in basement areas were flooded (1)

back up generators failed + ∴ no power for water coolant pumps (1)

Reactor cores overheated and the nuclear fuel melted down (1)

(e) What does the expression "corium" refer to in the aftermath of a nuclear reactor meltdown? (paragraph 3) (2 marks)

Corium is the molten material produced by a reactor meltdown (1)

consists of a mixture of nuclear fuel rods, control rods, fission products + structural material from reactor core (1)

(f) Loss of cooling after the tsunami caused overheating in the spent fuel pool due to decay heat (paragraph 4). Estimate a value for the

(i) quantity of decay heat produced every day in the spent fuel pool. (2 marks)

m_W boiled each day = 70 tonnes (1)

$Q = mL_v$

$= 70 \times 10^3 \times 2.26 \times 10^6$

$= 1.58 \times 10^{11}$

$= 1.6 \times 10^{11}$ J (1) (no more than 2 sig figs) $(-\frac{1}{2})$ if more than 2 sig figs

(ii) power of the decay heat in the spent fuel pool. (2 marks)

t = 1 day

$= 24 \times 60 \times 60$

$= 86{,}400$ s. (1)

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

$= \frac{1.6 \times 10^{11}}{86400}$

$= 1.8 \times 10$ W (1)

(no more than 2 sig figs $(-\frac{1}{2})$ if not)

(g) In the aftermath of the Fukushima diaster there have been no recorded deaths to workers who participated in the reactor cleanup. Describe two ways the workers could protect themselves from receiving harmful doses of radiation. (2 marks)

Any 2 suitable methods (1) mark each

- limiting time of exposure
- shielding – masks, gloves, overalls, goggles
- recording dosage + leaving site when set dosage recieved
- working remotely through robotic equipment.
- waiting for period of time till activity of site has decreased.

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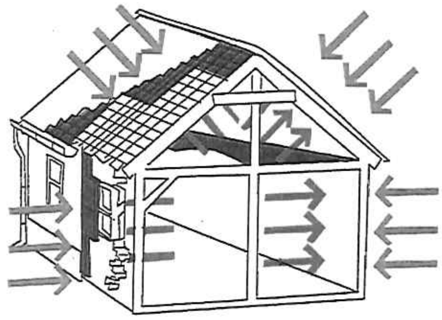
Question 22 **HOUSEHOLD INSULATION** **(18 marks)**

(Paragraph 1)
Insulation is material designed to prevent heat or sound from being transmitted from one area to another. It's normally used to keep heat and/or sound in or out of your home, or to confine it to certain parts of your house. Insulation can work in a number of different ways, but it most commonly incorporates materials that consist of millions of tiny pockets of still air. Still air is an extremely good insulator, and trapped pockets of air are what give most types of insulation their high thermal resistance.



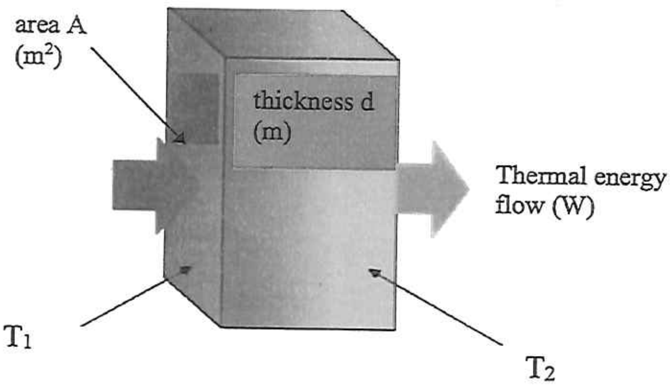
(Paragraph 2)
Thermal insulation is usually found in walls and ceilings, especially the outside walls of a home where heat is most likely to be gained or lost. Probably the first type of insulation people think of is some sort of batt, usually glasswool or rockwool; batts are light, fluffy panels of material that sit inside the frame of your home - typically either in wall spaces or in your ceiling. Batts are made of fibrous materials, and work by trapping tiny pockets of air within fibres. Other common types of insulation include blow-in cellulose (which is easier to install if the house has already been constructed), polyurethane foam, polyester matting and reflective foil. Each type works differently to trap or repel heat, and offers different advantages and disadvantages.

(Paragraph 3)
The effectiveness of thermal insulation is measured by its 'R-value'. The higher the R-value, the better the thermal insulation it provides. R-values are defined as the ratio of the thickness of the insulating material to the thermal conductivity of that material and can be calculated using the formula:

$$R = \frac{d}{k}$$

where d = thickness of material (m)
k = thermal conductivity ($Wm^{-1}K^{-1}$)

The rate at which thermal energy can pass through a material, expressed in watts, is found by multiplying the exposed surface area A of the material by the temperature difference (T_2 - T_1) between the two different sides of the material, and then dividing by the R-value of the material.



(Paragraph 4)
There are two ways R-values are specified: the R-value of the insulation material itself, known as the Rm, or the total R-value of the construction, known as the R_T. The total R-value includes all layers of materials in a construction, such as concrete, bricks, plasterboard, etc, and is the sum of the individual Rm-values of each layer of material. Reflective foil may be incorporated into a building system, as it is especially useful in keeping out heat in hot weather, but the reflective foil itself does NOT have a significant Rm-value.

(a) Glasswool or rockwool batts are light, fluffy panels made of fibrous materials (paragraph 2). What is the advantage of them being constructed in this way? (2 marks)

fibrous materials trap air pockets in materials (1)

air pockets increase thermal resistance as air is a poor conductor of heat (1)

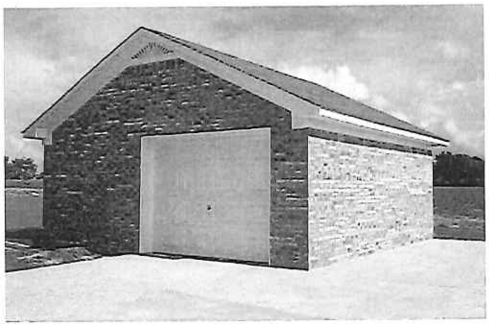
(b) In paragraph 1 the statement is made that thermal insulation "*commonly incorporates materials that consist of millions of tiny pockets of still air*". Why is it important that the air pockets are very small and hold only still air? (3 marks)

small still air pockets limit convection currents occurring in the material (1)

air pockets are poor thermal conductors (1)

∴ Heat transfer is minimised in the insulation (1)

(c) The north facing brick wall of a garage consists of a single layer of bricks, with a thermal conductivity of 0.70 $Wm^{-1}K^{-1}$, and a thickness of 11 cm. The wall is 6.0 metres in length and 2.75 metres in height. On a hot summer morning, the outside surface of the wall is at a temperature of 35°C while the inside surface is at a temperature of 25°C. Calculate



(i) the Rm-value of the brick wall. (2 marks)

$R_m = \frac{d}{k} = \frac{0.11}{0.70} = 0.157 \ m^2 K W^{-1}$
(1) (1)

(ii) the rate of heat flow through the wall on this hot summer morning. (3 marks)

Surface area of wall $A = 6.0 \times 2.75 = 16.5\ m^2$ ($\frac{1}{2}$)

$\Delta T = 35 - 25 = 10\ °C$ ($\frac{1}{2}$)

Rate of heat flow $\frac{Q}{t} = \frac{A(T_2 - T_1)}{R_m}$ (1)

$= \frac{16.5 \times 10}{0.157} = 1050\ W$ (1)

The owner of the garage decides to insulate the garage with polystyrene panels attached on the inside of the garage walls. The panels are 8.0 cm thick and the polystyrene has a thermal conductivity k = 0.033 $Wm^{-1}K^{-1}$. Now find

(iii) the RT-value of the composite brick/ polystyrene wall. (3 marks)

For polystyrene

$R_m = \frac{d}{k} = \frac{0.08}{0.033} = 2.42\ m^2KW^{-1}$ (1)

$\therefore R_T = R_{m\,brick} + R_{m\,polystyrene}$ (1)

$= 0.157 + 2.42$

$= 2.58\ m^2KW^{-1}$ (1)

#If used incorrect units or did not state units in (i) have not deducted $\frac{1}{2}$ mark If already deducted in part (i)

(iv) the rate of heat flow through the composite wall on a hot summer morning as described above. (2 marks)

Rate of flow $= \frac{A(T_2 - T_1)}{R_m}$ (1) $= \frac{16.5 \times 10}{2.58} = 64\ W$ (1)

(d) In paragraph 4, reflective foil is said to be "*especially useful in keeping out heat in hot weather, but the reflective foil itself does NOT have a significant Rm-value.*" Briefly explain

(i) how reflective foil keeps out heat in hot weather (1 mark)

Reflective foil reflects the IR radiation reducing heat transfer

(ii) why reflective foil does not have a significant Rm-value. (2 marks)

Reflective foil is very thin so small value of d ($\frac{1}{2}$)

foil made of metal so high thermal conductivity ($\frac{1}{2}$)

Value of $Rm = \frac{d}{k}$ ∴ Rm value is extremly small (1)

END OF PAPER