Methodist Ladies' College
ATAR course examination, Semester 2, 2018

Question/Answer Booklet

PHYSICS
ATAR Year 11

Student Name: _____

Teacher Name: _____

Time allowed for this paper
Reading time before commencing work: 10 minutes
Working time for paper: 3 hours

Materials required/recommended for this paper
To be provided by the supervisor
This Question/Answer booklet
Formulae and Data booklet

To be provided by the candidate
Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: non-programmable calculators approved for use in this examination, drawing templates, drawing compass and a protractor

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 material. 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 total exam	Your mark
Section One Short response	14	14	54	54	30%	
Section Two Problem-solving	6	6	90	90	50%	
Section Three Comprehension	2	2	36	36	20%	
			Total	**180**	**100%**	

Instructions to candidates

1. The rules for the conduct of ATAR course examinations are detailed in the *Year 11 Information Handbook 2018*. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer Booklet.

3. When calculating or estimating answers, show all your working clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning.

    In calculations, give final answers to three significant figures and include appropriate units where applicable.

    In estimates, give final answers to a maximum of two significant figures and include appropriate units where applicable.

4. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

5. Supplementary pages for the use planning/continuing your answer to a question have been provided at the end of the Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

6. The Formulae and Data Booklet is not to be handed in with your Question/Answer Booklet.

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 = _____ [1 mark]

Displacement = _____ [2 marks]

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)

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

(1 mark)

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.

4.00 Ω

6.00 Ω

A B
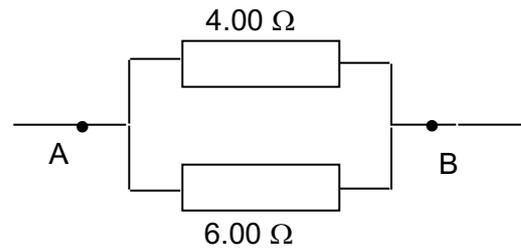
(a) State the voltage drop across each resistor.

4.00 Ω resistor: _____

6.00 Ω resistor: _____

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

4.00 Ω resistor: _____

6.00 Ω resistor: _____

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)

(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)

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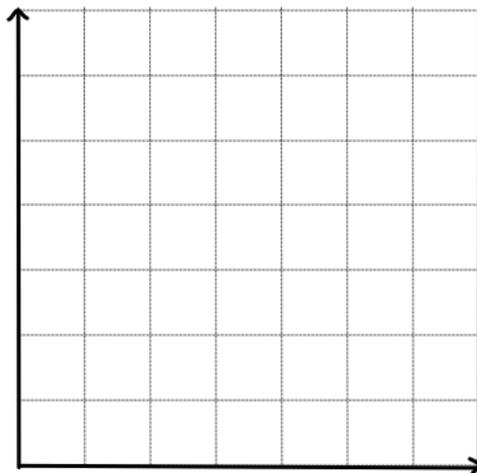
(b)   Use your graph to determine if the car would strike the pedestrian.   (2 marks)

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.

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)

(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)

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
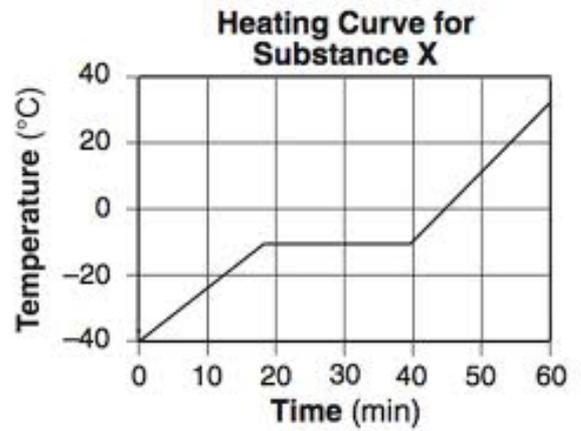
(a) melting point. (1 mark)

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

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

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. _____

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

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

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

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?
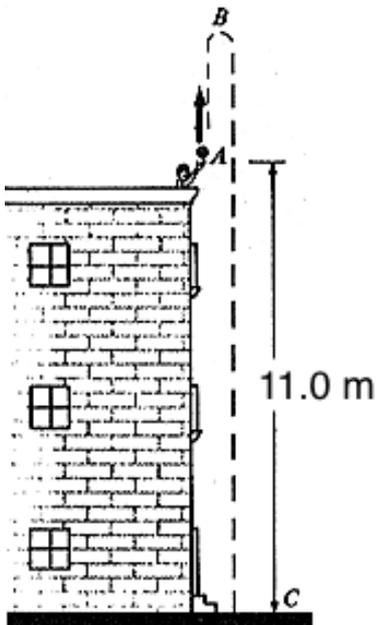
Question 12 **(3 marks)**

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.
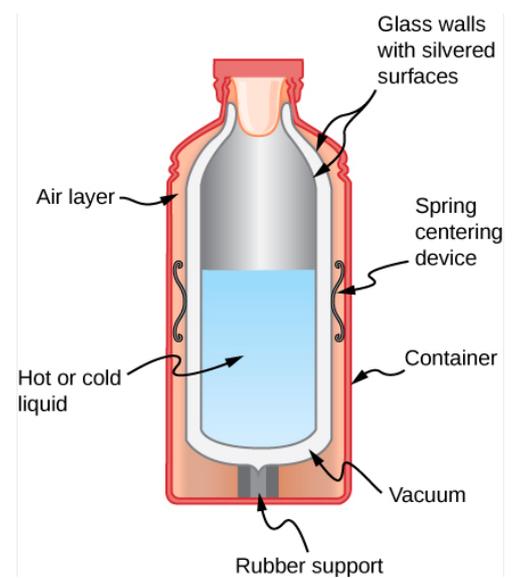
Question 13   **(4 marks)**

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)

11.0 m

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

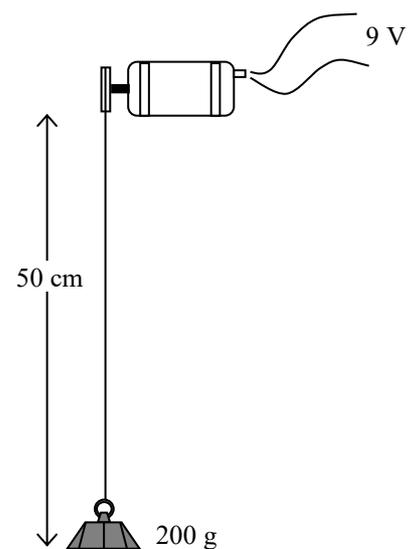**Question 14**   **(4 marks)**

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)

9 V

50 cm

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

200 g

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 added

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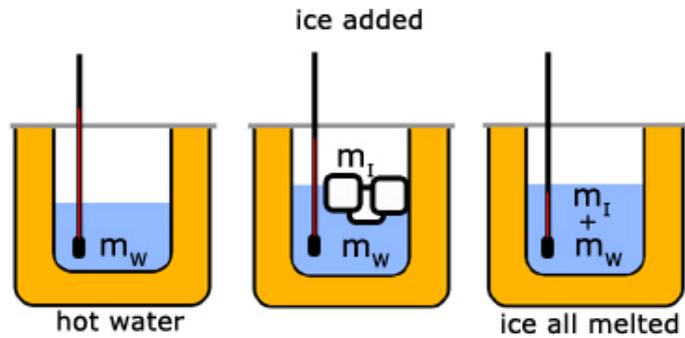
Ice was dried with paper towel and added to the hot water in the calorimeter and stirred continually until a significant temperature drop was recorded.

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)	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)		

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

(1 mark)

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

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

(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)

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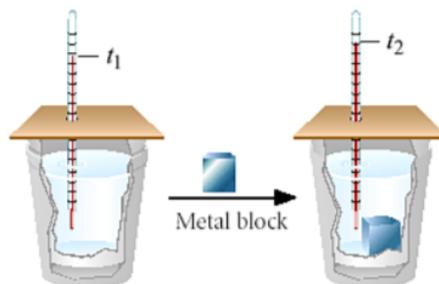
Assuming that heat transfer only occurs between
the metal and the water in the cup, calculate the specific heat of the metal.   (4 marks)

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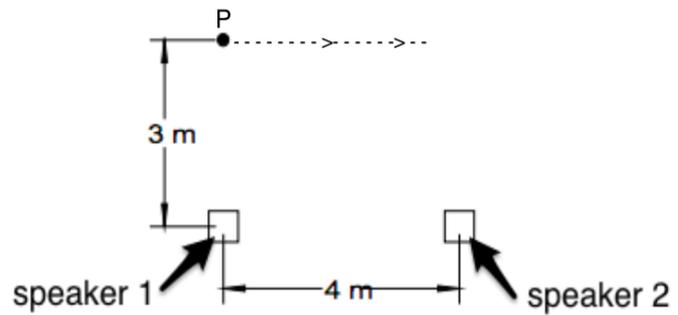
(a) Demonstrate through calculations whether you will hear a loud or a soft sound when standing at point P. (4 marks)

(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)

(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)

(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)

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

(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)

Time (ms)
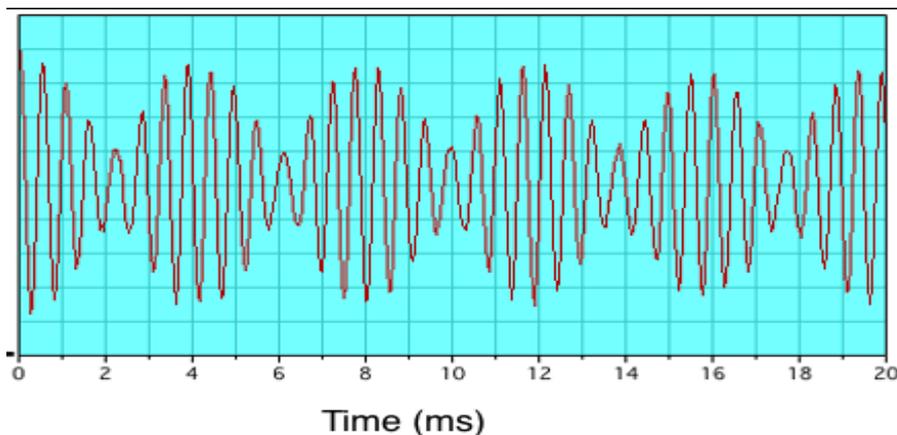
See next page

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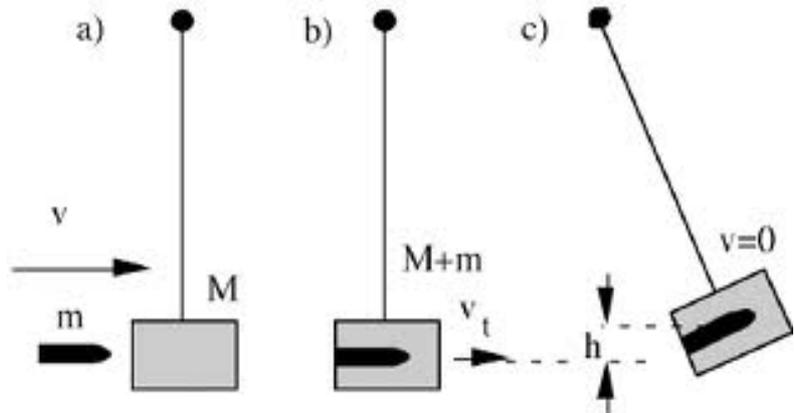
(a) The block (plus embedded bullet) swings upwards to a maximum height of 26.0 cm. Calculate their increase in gravitational potential energy. (2 marks)

(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)

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

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

(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)

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

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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}

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)

Technetium-99 isn't stable and finally ends up, following another Beta decay, as Ruthenium-99 as in the diagram below.
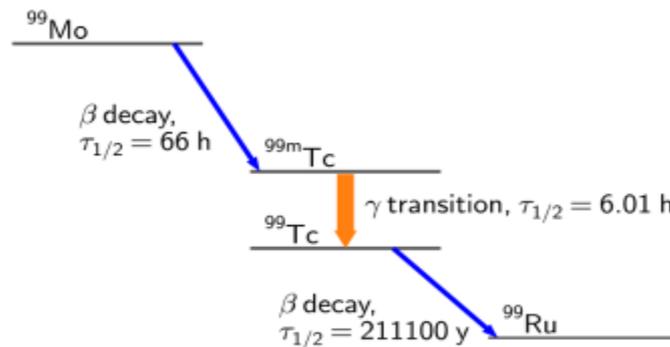
(b)   Technetium-99m emits gamma rays with energy of 140 keV. How many joules of energy are emitted with each gamma decay?   (1 mark)

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

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

     (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)

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)

(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)

(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)

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

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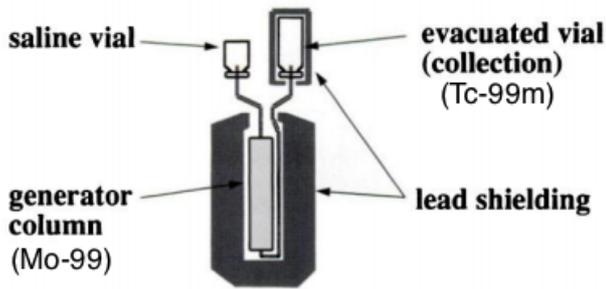
(g)   Describe the function of the lead shielding around the generator column.   (1 mark)

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

See next page

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		Device B	
Current (A)	Voltage (V)	Current (A)	Voltage (V)
0.00	0.00	0.00	0.00
0.93	0.99	0.13	1.37
1.23	2.00	0.26	2.66
1.49	2.93	0.40	3.94
1.68	3.76	0.51	5.05
1.99	5.20	0.63	6.23
2.12	5.82	0.73	7.19
2.24	6.41	0.84	8.26
2.32	6.94	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)

(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)
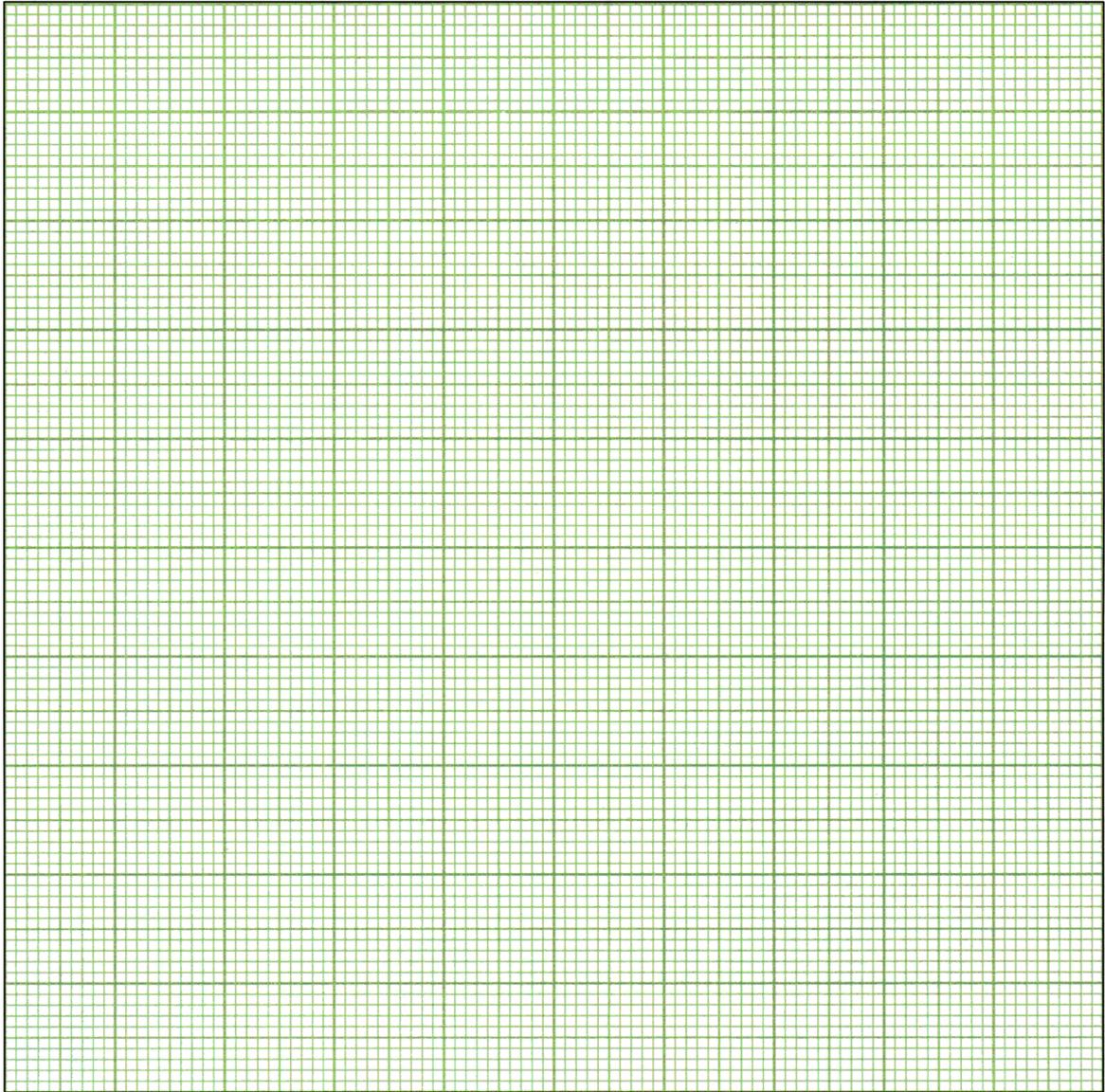
(d)   **Using your graph**, calculate the resistance of the component which is an **ohmic** conductor.   (2 marks)

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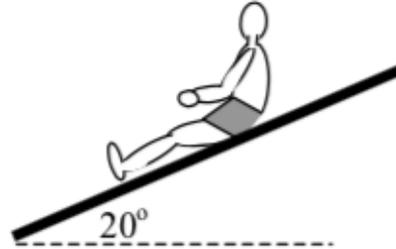
(a)   On the diagram (above right) show all the forces acting on Mr Biffin as he slides.

(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)

(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,

Boiling Water Reactor system
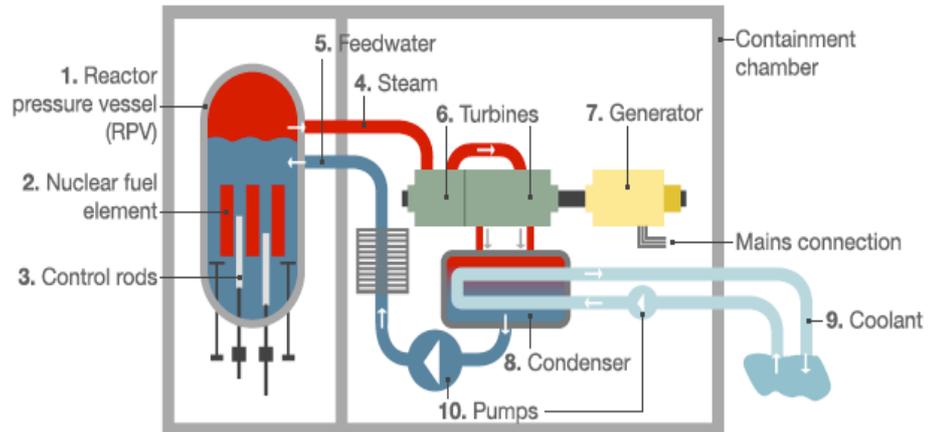
Source: RobbyBer/Wikimedia

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.

(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.

See next page

(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)

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

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

(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)

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

(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)

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

(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)

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.
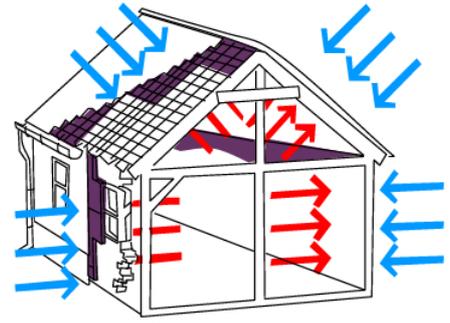
(Paragraph 2)
Thermal insulation is usually found in walls and ceilings, especially the outside walls of a home
where heat is most likely to be gained or lost. Probably the first type of insulation people think of
is some sort of batt, usually glasswool or rockwool; batts are light, fluffy panels of 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.
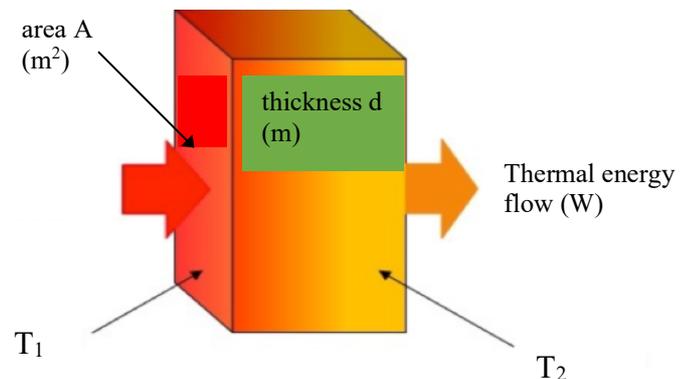
(Paragraph 3)
The effectiveness of thermal insulation is measured by its 'R-value'. The higher the R-value, the
better the thermal insulation it provides. R-values are defined as the ratio of the thickness of the
insulating material to the thermal conductivity of that material and can be calculated using 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.

See next page

(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)

(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)

(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 35ºC while the inside surface is at a temperature of 25ºC. Calculate

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

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

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)

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

See next page

(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)

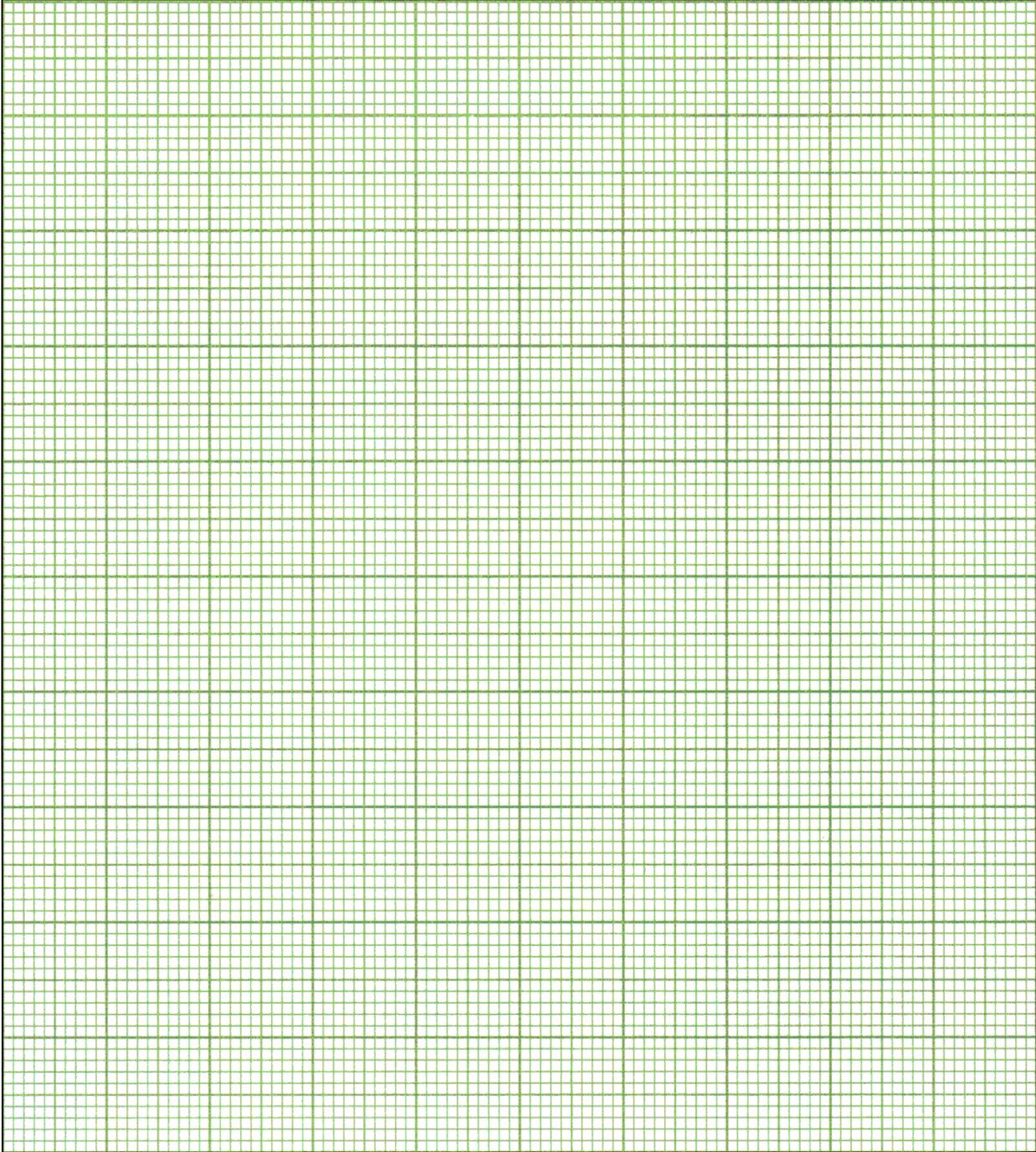   (ii)   why reflective foil does not have a significant Rm-value.   (2 marks)

END OF PAPER

EXTRA WORKING SPACE

EXTRA GRAPH PAPER