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MANA TOHU MĀTAURANGA O AOTEAROA

For Supervisor's use only

Level 1 Physics, 2008

90184 Demonstrate understanding of heat transfer and nuclear physics

Credits: Three
9.30 am Tuesday 25 November 2008

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should answer ALL the questions in this booklet.

For all numerical answers, full working must be shown. The answer should be given with an SI unit.

For all 'describe' or 'explain' questions, the answer should be in complete sentences.

Formulae you may find useful are given on page 2.

If you need more space for any answer, use the page(s) provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2–7 in the correct order and that none of these pages is blank.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

For Assessor's use only **Achievement Criteria**		
Achievement	**Achievement with Merit**	**Achievement with Excellence**
Identify or describe aspects of phenomena, concepts or principles.	Give descriptions or explanations in terms of phenomena, concepts, principles and / or relationships.	Give explanations that show clear understanding in terms of phenomena, concepts, principles and / or relationships.
Solve straightforward problems	Solve problems.	Solve complex problems.
Overall Level of Performance (all criteria within a column are met)		

You are advised to spend 30 minutes answering the questions in this booklet.

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You may find the following formulae useful.

$$Q = mc\Delta T \qquad Q = mL \qquad P = \frac{E}{t}$$

QUESTION ONE: NUCLEAR ENERGY

Plutonium-239 is used in some nuclear fission reactors as a fuel. Plutonium has many isotopes, including plutonium-239 (atomic mass of 239) and plutonium-241 (atomic mass of 241).

(a) Describe ONE similarity and ONE difference between plutonium-239 and plutonium-241.

Similarity ______________________________

____

Difference ______________________________

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(b) The nucleus of the plutonium-241 atom has 94 positively charged particles in it.

Calculate the number of neutrons in the nucleus.

____

____

neutrons ______________

(c) Uranium is also used as fuel in a fission reactor.

Describe what happens to the nucleus of the uranium atom when fission occurs.

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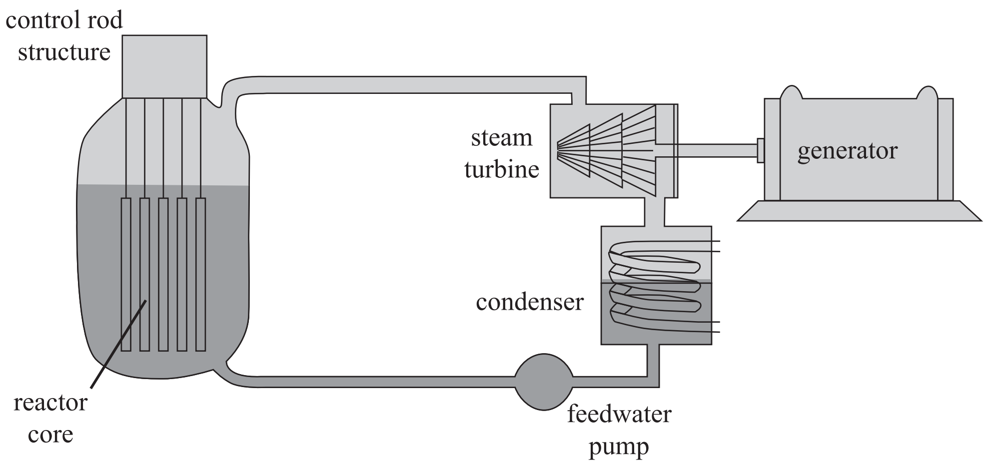
The diagram below shows a type of nuclear reactor called a Boiling Water Reactor. In this reactor, the water constantly passes over the reactor core to produce steam. The steam is then used to turn the generator. The water that passes over the reactor core also acts as a moderator and a coolant.



(d) Explain why the reactor core stays hot even though water is constantly running through it.

(e) Explain how the water that passes over the reactor core acts as a **moderator** and a **coolant**.

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(f) In a Boiling Water Reactor, **1 300 kg** of water is turned into steam in **one second**. The water inside the reactor boils at **300°C**, due to high pressure inside the reactor. The initial temperature of the water that enters the reactor core is **270°C**.

The specific heat capacity of water is 4 200 J kg^{-1} $°C^{-1}$.
The latent heat of vaporisation of water is 2.27×10^6 J kg^{-1}.

Calculate the power output of the reactor.

power ______________

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QUESTION TWO: NUCLEAR HEATERS

Radioisotope heater units are small nuclear heaters used to keep instruments inside a spacecraft warm during space travel. They are sealed units, which produce a continuous supply of heat for many years. Heat is generated by the breaking down of the plutonium-238 nucleus.

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http://www.daviddarling.info/images/radioisotope_heater_unit.jp

Plutonium (Pu) in the radioisotope heater breaks down into uranium and helium nuclei. The following equation shows the reaction.

$$^{238}_{x}\text{Pu} \rightarrow {}^{y}_{92}\text{U} + {}^{4}_{2}\text{He}$$

(a) Calculate the values of ***x*** and ***y*** in the above equation

x ________________ y ________________

(b) The average power output of one radioisotope heater unit is **1.4 watts**.

Calculate the total amount of heat energy released by the unit in **one year** (365 days).

heat energy ________________

(c) The sealed container is painted black on both the inside and the outside.

Explain how this maximises the transfer of heat in the vacuum of space.

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David is investigating the possibility of using the radioisotope heater units to melt ice in places like Antarctica where the ice temperature is **–35°C**.

(d) Calculate the heat energy required to increase the temperature of **200 g** of ice at **–35°C** to ice at **0°C**. The specific heat capacity of ice is 2 100 J kg^{-1} °C^{-1}.

heat energy ______________

(e) David sets up an experiment in the laboratory. He places 8 radioisotope heater units in a glass jug containing 200 g of ice at 0°C. He puts a lid on the glass jug and wraps the jug with several layers of wool.

Explain why the lid and the wool wrap improve the heating process.

(f) David calculates that the radioisotope heater units should release **120 960 J** of heat energy over a three hour period. The heat required to melt 200 g of ice at 0°C to water at 0°C is 68 000 J, and the heat loss to the glass jar and the wool wrapping is **10 500 J**. The specific heat capacity of water is 4 200 J kg^{-1} °C^{-1}.

Calculate the expected temperature of the water at the end of the three-hour period.

temperature ______________

Extra paper for continuation of answers if required.
Clearly number the question.

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Question number