M13/4/PHYSI/SP2/ENG/TZ2/XX

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PHYSICS
STANDARD LEVEL
PAPER 2

Candidate session number

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Monday 6 May 2013 (morning)

1 hour 15 minutes

Examination code

2	2	1	3	–	6	5	1	7

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all questions.
- Section B: answer one question.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the ***Physics*** *Data Booklet* is required for this paper.
- The maximum mark for this examination paper is *[50 marks]*.

0124

23 pages

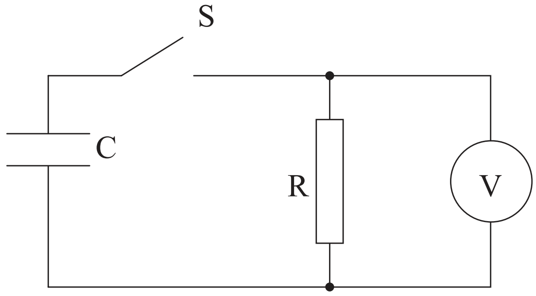
SECTION A

*Answer **all** questions. Write your answers in the boxes provided.*

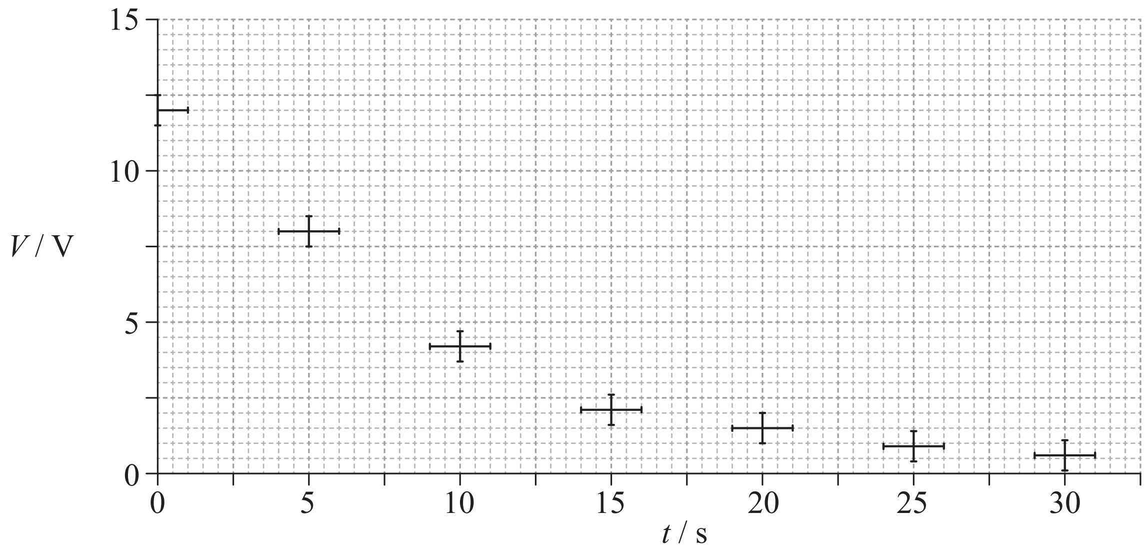
A1. Data analysis question.

A capacitor is a device that can be used to store electric charge.

(a) An experiment was undertaken to investigate one of the circuit properties of a capacitor. A capacitor C was connected via a switch S to a resistance R and a voltmeter V.



The initial potential difference across C was 12 V. The switch S was closed and the potential difference V across R was measured at various times t. The data collected, along with error bars, are shown plotted below.



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(Question A1 continued)

(i) On the graph opposite, draw a best-fit line for the data starting from $t = 0$. *[2]*

(ii) It was hypothesized that the decay of the potential difference across the capacitor is exponential. Determine, using the graph, whether this hypothesis is true **or** not. *[4]*

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(b) The time constant τ of the circuit is defined as the time it would take for the capacitor to discharge were it to keep discharging at its initial rate. Use the graph in (a) to calculate the

(i) initial rate of decay of potential difference V. *[2]*

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(ii) time constant τ. *[1]*

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(This question continues on the following page)

(Question A1 continued)

(c) The time constant $\tau = RC$ where R is the resistance and C is a property called capacitance. The effective resistance in the circuit is $10\,\text{M}\Omega$. Calculate the capacitance C. *[1]*

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A2. This question is about kinematics.

(a) Fiona drops a stone from rest vertically down a water well. She hears the splash of the stone striking the water 1.6 s after the stone leaves her hand. Estimate the

(i) distance between Fiona's hand and the water surface. *[1]*

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(ii) speed with which the stone hits the water. *[2]*

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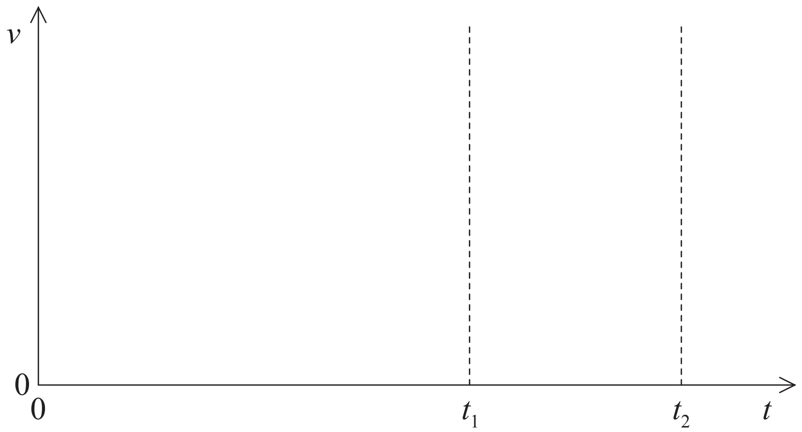
(This question continues on the following page)

(Question A2 continued)

(b) After the stone in (a) hits the water surface it rapidly reaches a terminal speed as it falls through the water. The stone leaves Fiona's hand at time $t=0$. It hits the water surface at t_1 and it comes to rest at the bottom of the water at t_2. Using the axes below, sketch a graph to show how the speed v of the stone varies from time $t=0$ to just before $t=t_2$. (There is no need to add any values to the axes.) *[3]*



(c) Draw and label a free-body diagram representing the forces acting on the stone as it falls through the water at its terminal speed. *[2]*

A3. This question is about power production.

(a) The Drax coal-fired power plant has a power output of 4.0 GW. The efficiency of the plant is 40 %. The energy density of the coal used is 24 MJ kg^{-1}. Estimate the minimum mass of coal that is burned each year (1 year $= 3.2 \times 10^7$ s). *[3]*

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(b) Discuss **one** advantage and **one** disadvantage of using nuclear power production compared to using coal-fired power production. *[4]*

Advantage: . . . .

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Disadvantage: . . . .

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SECTION B

*This section consists of three questions: B1, B2 and B3. Answer **one** question. Write your answers in the boxes provided.*

B1. This question is in **two** parts. **Part 1** is about nuclear reactions and radioactive decay. **Part 2** is about thermal concepts.

Part 1 Nuclear reactions and radioactive decay

(a) The isotope tritium (hydrogen-3) has a radioactive half-life of 12 days.

(i) State what is meant by the term isotope. *[1]*

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(ii) Define *radioactive half-life*. *[1]*

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(This question continues on the following page)

(Question B1, part 1 continued)

(b) Tritium may be produced by bombarding a nucleus of the isotope lithium-7 with a high-energy neutron. The reaction equation for this interaction is

$$^{7}_{3}\text{Li} + ^{1}_{0}\text{n} \rightarrow ^{3}_{1}\text{H} + ^{4}_{Z}\text{X} + ^{1}_{0}\text{n}.$$

(i) Identify the proton number Z of X. *[1]*

Z= . . . .

(ii) Use the following data to show that the minimum energy that a neutron must have to initiate the reaction in (b)(i) is about 2.5 MeV. *[2]*

Rest mass of lithium-7 nucleus	= 7.0160 u
Rest mass of tritium nucleus	= 3.0161 u
Rest mass of X nucleus	= 4.0026 u

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(c) Assuming that the lithium-7 nucleus in (b) is at rest, suggest why, in terms of conservation of momentum, the neutron initiating the reaction must have an energy greater than 2.5 MeV. *[2]*

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(Question B1, part 1 continued)

(d) A nucleus of tritium decays to a nucleus of helium-3. Identify the particles X and Y in the nuclear reaction equation for this decay. *[2]*

$$ {}^{3}_{1}\text{H} \rightarrow {}^{3}_{2}\text{He} + \text{X} + \text{Y} $$

X: . . . .

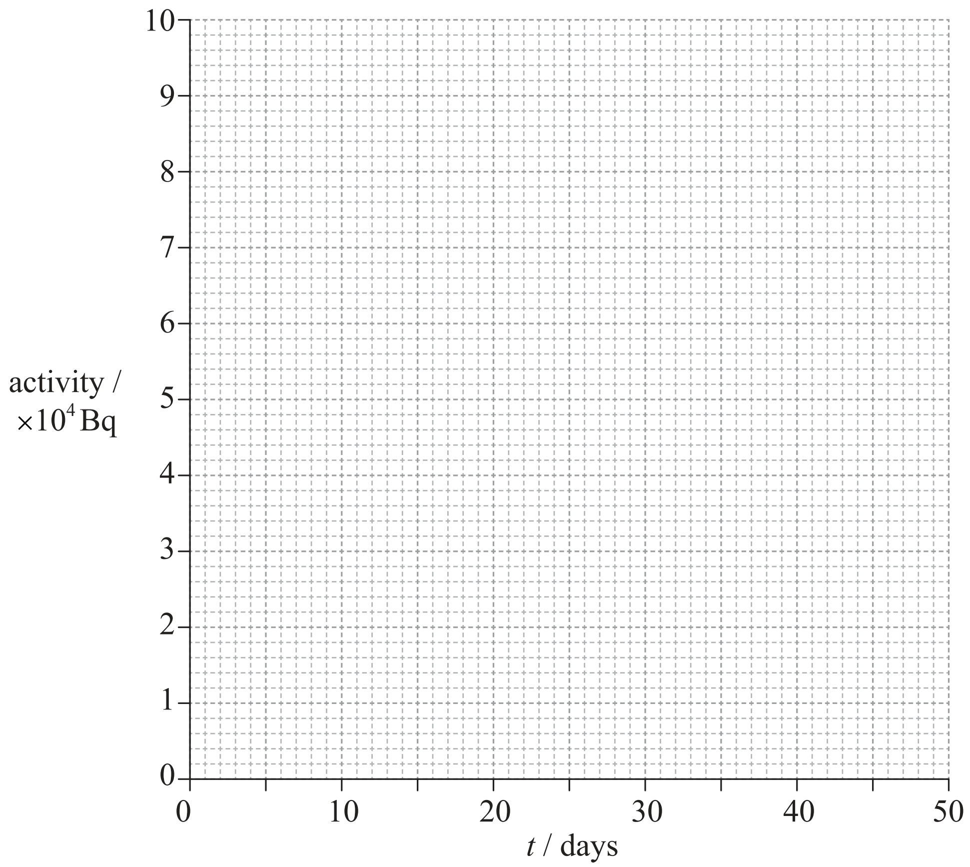
Y: . . . .

(This question continues on the following page)

(Question B1, part 1 continued)

(e) A sample of tritium has an activity of 8.0×10^{4} Bq at time $t = 0$. The half-life of tritium is 12 days.

(i) Using the axes below, construct a graph to show how the activity of the sample varies with time from $t = 0$ to $t = 48$ days. *[2]*



(ii) Use the graph to determine the activity of the sample after 30 days. *[1]*

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(Question B1, part 1 continued)

(iii) The activity of a radioactive sample is proportional to the number of atoms in the sample. The sample of tritium initially consists of 1.2×10^{11} tritium atoms. Determine, using your answer to (e)(ii) the number of tritium atoms remaining after 30 days. *[2]*

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Part 2 Thermal concepts

(a) Distinguish between internal energy and thermal energy (heat). *[2]*

Internal energy:

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Thermal energy:

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(Question B1, part 2 continued)

(b) A 300 W immersion heater is placed in a beaker containing 0.25 kg of water at a temperature of 18 °C. The heater is switched on for 120 s, after which time the temperature of the water is 45 °C. The thermal capacity of the beaker is negligible and the specific heat capacity of water is $4.2\times10^{3}\,\text{J kg}^{-1}\,\text{K}^{-1}$.

(i) Estimate the change in internal energy of the water. *[2]*

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(ii) Determine the rate at which thermal energy is transferred from the water to the surroundings during the time that the heater is switched on. *[2]*

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(Question B1, part 2 continued)

(c) The water in (b) is further heated until it starts to boil at constant temperature. It is boiled for 500 s measured from the time that it first starts to boil. The mass of water remaining after this time is 0.20 kg.

(i) Estimate, using the answer to (b)(ii), the specific latent heat of vaporization of the water. *[2]*

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(ii) Explain, in terms of the energy of the molecules of the water, why the water boils at constant temperature. *[3]*

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B2. This question is in **two** parts. **Part 1** is about electric charge and electric circuits. **Part 2** is about momentum.

Part 1 Electric charge and electric circuits

(a) State Coulomb's law. *[2]*

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(b) In a simple model of the hydrogen atom, the electron can be regarded as being in a circular orbit about the proton. The radius of the orbit is 2.0×10^{-10} m.

(i) Determine the magnitude of the electric force between the proton and the electron. *[2]*

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(ii) Calculate the magnitude of the electric field strength E and state the direction of the electric field due to the proton at a distance of 2.0×10^{-10} m from the proton. *[2]*

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(Question B2, part 1 continued)

(iii) The magnitude of the gravitational field due to the proton at a distance of 2.0×10^{-10} m from the proton is H.

Show that the ratio $\frac{H}{E}$ is of the order $10^{-28}\,\mathrm{C\,kg^{-1}}$. *[2]*

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(iv) The orbital electron is transferred from its orbit to a point where the potential is zero. The gain in potential energy of the electron is 5.4×10^{-19} J. Calculate the value of the potential difference through which the electron is moved. *[1]*

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(Question B2, part 1 continued)

(c) An electric cell is a device that is used to transfer energy to electrons in a circuit. A particular circuit consists of a cell of emf ε and internal resistance r connected in series with a resistor of resistance $5.0\,\Omega$.

(i) Define *emf of a cell*. *[1]*

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(ii) The energy supplied by the cell to one electron in transferring it around the circuit is 5.1×10^{-19} J. Show that the emf of the cell is 3.2 V. *[1]*

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(iii) Each electron in the circuit transfers an energy of 4.0×10^{-19} J to the $5.0\,\Omega$ resistor. Determine the value of the internal resistance r. *[4]*

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(Question B2 continued)

Part 2 Momentum

(a) Define *linear momentum*. *[1]*

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(b) State the law of conservation of momentum. *[2]*

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(c) Far from any massive object, a space rocket is moving with constant velocity. The engines of the space rocket are turned on and it accelerates by burning fuel and ejecting gases. Discuss how the law of conservation of momentum relates to this situation. *[3]*

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(Question B2, part 2 continued)

(d) Jane and Joe are two ice skaters initially at rest on a horizontal skating rink. They are facing each other and Jane is holding a ball. Jane throws the ball to Joe who catches it. The speed at which the ball leaves Jane, measured relative to the ground, is $8.0\,\text{m s}^{-1}$. The following data are available.

Mass of Jane = 52 kg
Mass of Joe = 74 kg
Mass of ball = 1.3 kg

Use the data to calculate the

(i) speed v of Jane relative to the ground immediately after she throws the ball. *[2]*

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(ii) speed V of Joe relative to the ground immediately after he catches the ball. *[2]*

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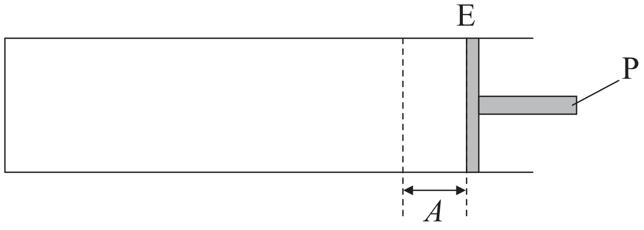
B3. This question is in **two** parts. **Part 1** is about simple harmonic motion (SHM) and waves. **Part 2** is about wind power and the greenhouse effect.

Part 1 Simple harmonic motion (SHM) and waves

(a) A gas is contained in a horizontal cylinder by a freely moving piston P. Initially P is at rest at the equilibrium position E.



The piston P is displaced a small distance *A* from E and released. As a result, P executes simple harmonic motion (SHM).

Define *simple harmonic motion* as applied to P. *[2]*

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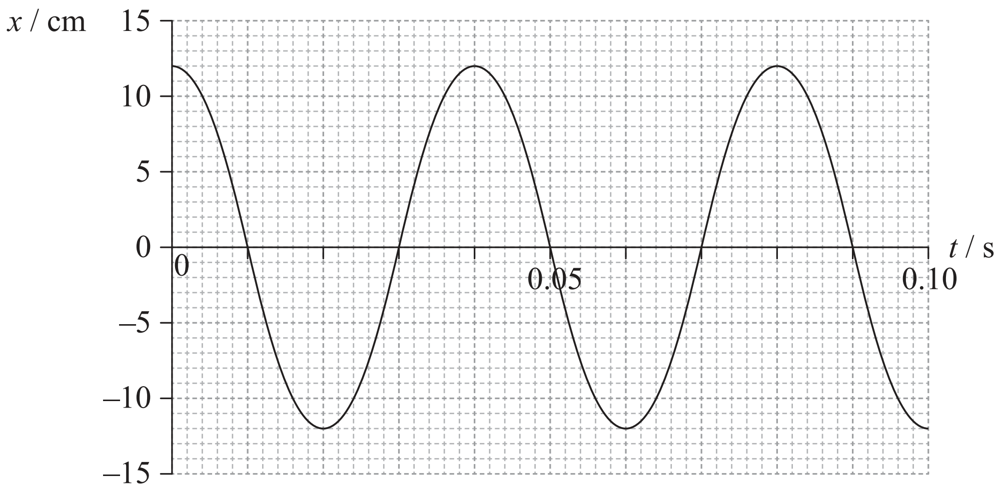
(Question B3, part 1 continued)

(b) The graph shows how the displacement x of the piston P in (a) from equilibrium varies with time t.



(i) State the value of the displacement A as defined in (a). *[1]*

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(ii) On the graph identify, using the letter M, a point where the magnitude of the acceleration of P is a maximum. *[1]*

(iii) Determine, using data from the graph and your answer to (b)(i), the magnitude of the maximum acceleration of P. *[3]*

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(Question B3, part 1 continued)

(iv) The mass of P is 0.32 kg. Determine the kinetic energy of P at $t = 0.052$ s. *[2]*

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(c) The oscillations of P initially set up a longitudinal wave in the gas.

(i) Describe, with reference to the transfer of energy, what is meant by a longitudinal wave. *[2]*

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(ii) The speed of the wave in the gas is $340\,\text{m}\,\text{s}^{-1}$. Calculate the wavelength of the wave in the gas. *[2]*

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(Question B3 continued)

Part 2 Wind power and the greenhouse effect

(a) A coal-fired power station has a power output of 4.0 GW. It has been suggested that a wind farm could replace this power station. Using the data below, determine the area that the wind farm would occupy in order to meet the same power output as the coal-fired power station. *[4]*

Radius of wind turbine blades = 42 m
Area required by each turbine = 5.0×10^{4} m^{2}
Efficiency of a turbine = 30 %
Average annual wind speed = 12 m s^{-1}
Average annual density of air = 1.2 kg m^{-3}

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(b) Wind power does not involve the production of greenhouse gases. Outline why the surface temperature of the Earth is higher than would be expected without the greenhouse effect. *[3]*

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(Question B3, part 2 continued)

(c) The average solar intensity incident at the surface of the Earth is $238\,\text{W}\,\text{m}^{-2}$.

(i) Assuming that the emissivity of the surface of the Earth is 1.0, estimate the average surface temperature if there were no greenhouse effect. *[2]*

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(ii) The enhanced greenhouse effect suggests that in several decades the predicted temperature of the atmosphere will be 250 K. The emissivity of the atmosphere is 0.78. Show that this atmospheric temperature increase will lead to a predicted average Earth surface temperature of 292 K. *[3]*

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Please **do not** write on this page.

Answers written on this page
will not be marked.