Diploma Programme
Programme du diplôme
Programa del Diploma

Astronomy
Standard level
Paper 2

Friday 28 April 2017 (morning)

1 hour 30 minutes

Candidate session number

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 all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the astronomy data booklet is required for this examination paper.
- The maximum mark for this examination paper is **[60 marks]**.

16 pages

2217 – 9005

Section A

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

1. The dominant nuclear reaction in the core of the Sun is the ppI chain, shown below:

$$4\,{}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + 2\mathrm{e}^{+} + \mathrm{X} + 2\gamma$$

(a) The above reaction shows four protons taking part in the reaction.

(i) State what missing part of the ppI chain is represented by X in the reaction above. [1]

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(ii) Explain the formation of X. [2]

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(b) Outline what happens to the following products of the ppI chain immediately following the completion of a ppI reaction:

(i) the helium nucleus [1]

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(Question 1 continued)

(ii) the positrons [3]

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(iii) the γ-rays [2]

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(c) Estimate how much time it takes for the γ-rays to reach the outer edge of the photosphere. [1]

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2. This question is about accretion and differentiation within the developing solar system.

(a) Give **one** piece of evidence that the Earth is a differentiated planet. [1]

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(b) Callisto is the second largest moon of Jupiter.

Figure 1: Callisto

[Source: http://solarsystem.nasa.gov]

It is believed that Callisto is at most, only weakly differentiated.

State what this suggests about its mode of formation and its subsequent thermal history. [2]

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(Question 2 continued)

(c) Explain how the giant impact theory of the Moon's origin can account for the lack of water on the Moon. [3]

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(d) State **three** ways in which a crater can be established as being due to an impact. [3]

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(e) Io is one of the moons of Jupiter and it is smaller than the Earth. Suggest why the smaller size of Io compared to the Earth might lead to a steady effusive flow onto the ground rather than explosive volcanism. [1]

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will not be marked.

3. This question is about stellar observation of galaxies.

(a) Explain with the aid of a diagram why the disc of the Milky Way galaxy, when seen from the Earth, is a band of light encircling the sky. [3]

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(b) If the Earth were in an elliptical galaxy, state **three** ways in which our view of the night sky would be different. [3]

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(c) Explain why open clusters are concentrated in the galactic disc of the Milky Way while the lower-metallicity globular clusters are not. [4]

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4. This question is about the density of the universe and its link to spacetime.

The critical density for the universe is given by

$$\rho_0 = \frac{3H_0^2}{8\pi G}$$

(a) Outline what is meant by the term critical density. You should include the meaning of the symbols in the formula for the critical density. [3]

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(b) Using the expression given above and a measured value for Hubble's constant of $72\,\text{km s}^{-1}\,\text{Mpc}^{-1}$, show that the current value for the critical density is approximately $1 \times 10^{-26}\,\text{kg m}^{-3}$.

Your answer should be given to **two** significant figures. [3]

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(Question 4 continued)

(c) Assuming that the mass of a hydrogen atom is 1.7×10^{-27} kg, determine the required number density of hydrogen molecules to produce a flat spacetime. [4]

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will not be marked.

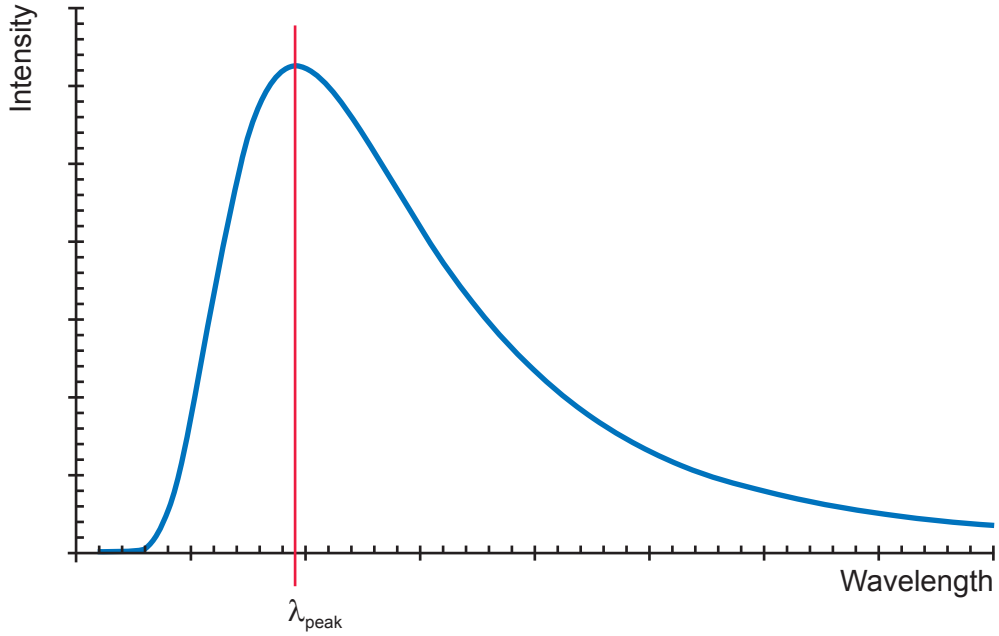
Section B

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

5. This question is about Wien's displacement law.

Opaque objects that are in (quasi) thermal equilibrium with their surroundings emit electromagnetic radiation with a characteristic Planck curve showing how the power output depends on wavelength, λ.

Figure 2: The Planck Curve for a black body.



It has been shown that the value for the peak wavelength, λ_{peak}, is related to the absolute temperature of the object.

Table 1 gives data for the λ_{peak} at different temperatures. The uncertainty in the temperature is negligible.

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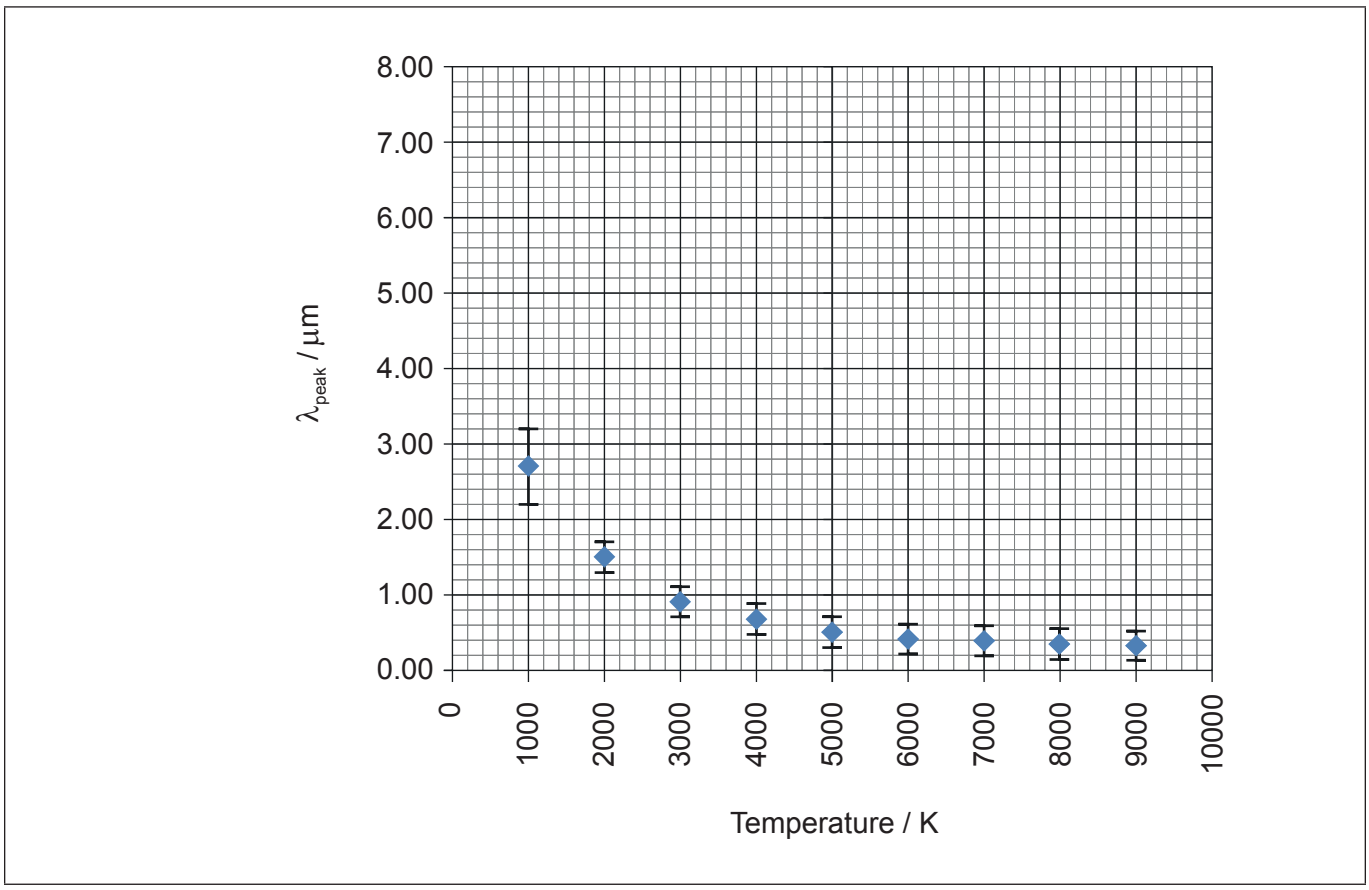
(Question 5 continued)

Table 1: Temperature – λ_{peak} data.

Temperature / K	λ_{peak} / μm	$\Delta\lambda_{peak}$ / μm
500	6.20	0.5
1000	2.90	0.5
2000	1.40	0.2
3000	0.95	0.2
4000	0.70	0.2
5000	0.55	0.2
6000	0.45	0.2
7000	0.40	0.2
8000	0.35	0.2
9000	0.32	0.2

(a) **Figure 3** shows the data plotted from **Table 1**. One data point is missing. Plot the missing point on the graph, including its error bar. [2]

Figure 3: T – λ_{peak} for a black body.



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(Question 5 continued)

(b) (i) On the graph, draw a best-fit line through the data points. [2]

(ii) Outline how you decided on your best-fit line. [1]

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(c) A student suggests that the variation shown in Figure 3 could be an inverse proportionality.

(i) Outline what this would mean in terms of λ_{peak} and T. [1]

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(ii) Determine, using your best-fit line from (b), whether this would be a valid suggestion. [2]

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(Question 5 continued)

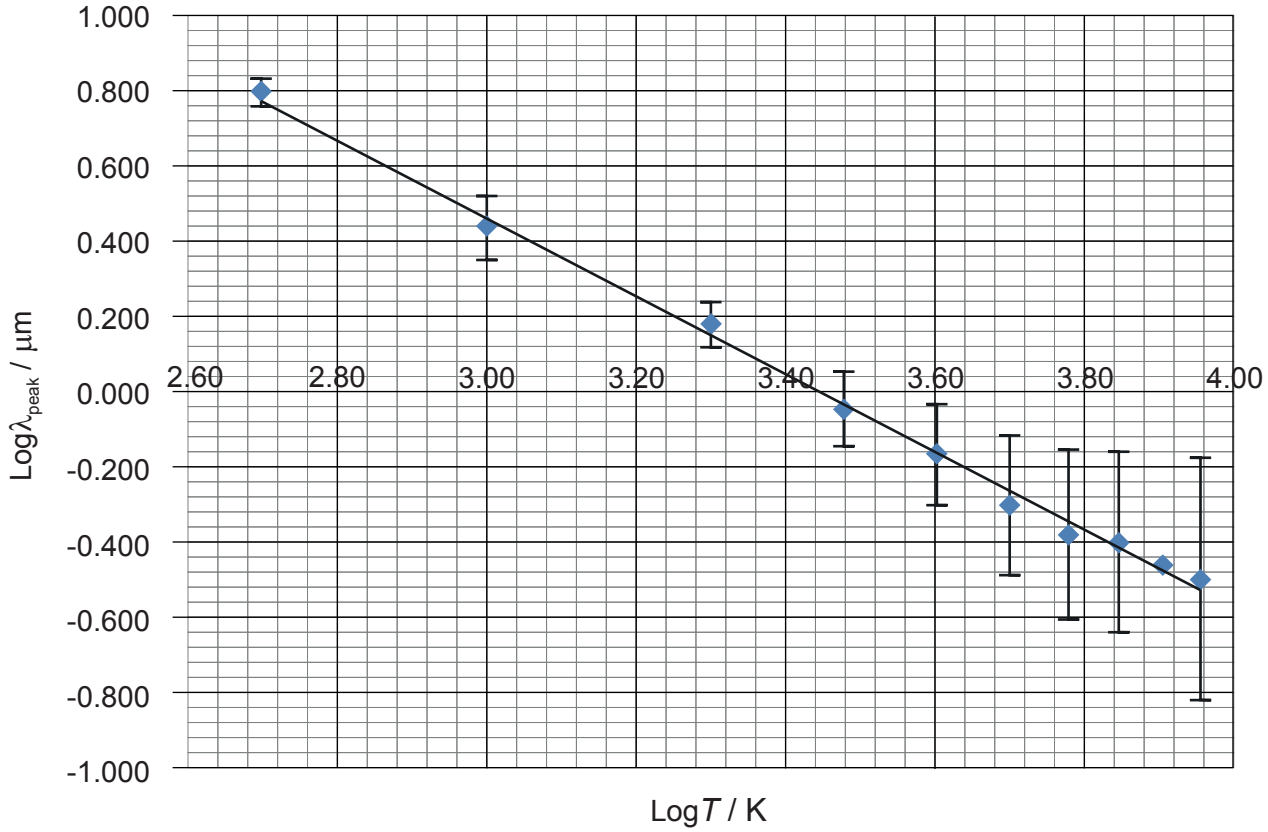
(d) Another student suggests that the form of the variation shown in Figure 3 could be a power law of the form:

$$\lambda_{peak} = AT^n$$

Hence they write: $\text{Log}\,\lambda_{peak} = \text{Log}A + n\text{Log}T$

A second graph is produced (Figure 4) for $\text{Log}\,\lambda_{peak}$ vs $\text{Log}\,T$.

Figure 4



(i) State how the graph in Figure 4 supports the suggestion of a power law. [1]

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(Question 5 continued)

(ii) Determine the value of the absolute uncertainty for the data point associated with a temperature of 8000 K. [2]

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(iii) State the significance of the gradient and intercept in Figure 4 to the original equation $\lambda_{peak} = AT^n$. [2]

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(e) Determine the gradient of the best fit line using Figure 4. [2]

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(f) Determine the intercept of the best fit line using Figure 4. [2]

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(Question 5 continued)

(g) Calculate the values for n and A in the equation in (d) based on your answers to (e) and (f). [2]

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(h) State the units for A. [1]

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