Diploma Programme
Programme du diplôme
Programa del Diploma

Astronomy
Standard level
Paper 2

Friday 27 April 2018 (morning)

Candidate session number

1 hour 30 minutes

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]**.

2218 – 9005

Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

1. An asteroid moves in a circular orbit with a measured orbital speed of $17\,\text{km}\,\text{s}^{-1}$.

(a) Distinguish between asteroids and comets, with reference to their location. [2]

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(b) (i) Calculate the asteroid's distance to the Sun to a suitable number of significant figures. [2]

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(ii) Calculate the asteroid's orbital period in years. [2]

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(iii) After a close encounter with another object, the orbital radius of the asteroid decreases. State how the asteroid's kinetic and potential energy changes. [2]

Kinetic energy: . . . . . .
. . . . . .

Potential energy: . . . . . .
. . . . . .

(This question continues on the following page)

(Question 1 continued)

(c) The asteroid now moves in an elliptical orbit. Demonstrate, without calculation, that the asteroid's velocity is greater at perihelion than at any other time in its new orbit. [3]

. . . . . .

. . . . . .

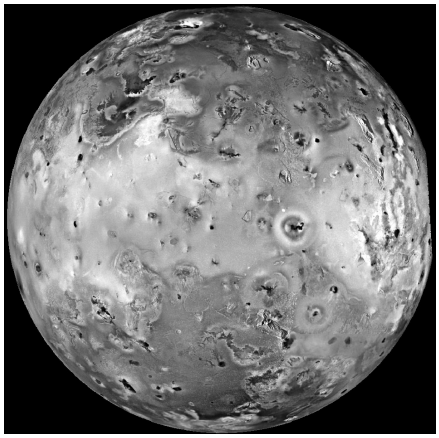
. . . . . .

. . . . . .

. . . . . .

. . . . . .

2. A number of theories describe the formation of planets and moons. The photograph shows the moon Io.



[https://apod.nasa.gov]

(a) Io is one of the four larger moons of Jupiter. Scientists think that Io is affected by tidal heating caused by Jupiter and its other moons. Identify **one** piece of evidence on Io's surface that supports this hypothesis. [1]

. . . . . .

. . . . . .

(b) Scientists believe the larger moons of Saturn formed from its rings. Explain why the remaining rings are not capable of forming large moons. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 2 continued)

(c) The cores of the larger planets are kept warm by radioactive decay. Deduce that the core temperature must decrease with time. [3]

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(d) Planets are said to be differentiated. State what is meant by this. [1]

. . . . . .
. . . . . .

(e) An early model suggested the Earth has a hollow internal structure with large cavities, including seas and air deep under the crust. Later evidence showed this to be incorrect. Demonstrate, with reference to the composition of Earth, that this hypothesis should be rejected. [3]

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

3. The quasar HS 1227 + 4530 was measured with a redshift of 0.19. Old images show the quasar in a field with several stars.

(a) Quasars are rarely discovered by viewing images. Suggest why this is the case. [1]

. . . . . .
. . . . . .

(b) Show that the distance to this quasar is approximately 800 Mpc. [2]

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(c) Determine the time it takes for the light from this quasar to reach Earth. [2]

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(d) Astronomers believe that quasars are formed by a black hole at the centre of a parent galaxy. Describe **one** piece of evidence that supports this theory. [2]

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question 3 continued)

(e) After discovering quasars, astronomers found that the lines in their spectra could not be identified with any known chemical elements. Suggest why they did not propose that the lines were formed by new chemical elements. [1]

. . . . . .

. . . . . .

(f) A supernova appeared in a galaxy at a distance of 65 million light-years. Its maximum brightness was $7.6 \times 10^{-13}\,\text{Wm}^{-2}$. Estimate the peak luminosity of this supernova. [3]

. . . . . .

. . . . . .

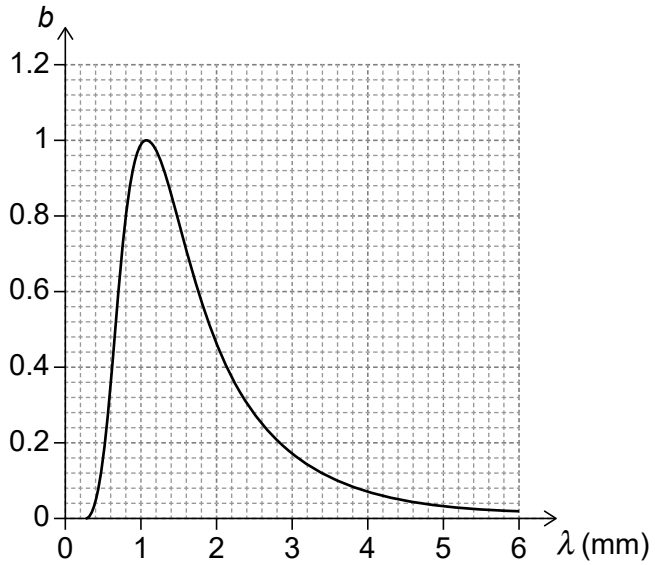
. . . . . .

. . . . . .

. . . . . .

. . . . . .

4. The figure shows the spectrum of cosmic microwave background (CMB) radiation. The relative brightness b is shown as a function of wavelength λ.



(a) Estimate the temperature of the cosmic microwave background (CMB) radiation. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) Explain why the temperature of the cosmic microwave background (CMB) radiation today is lower than in the early universe. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 4 continued)

(c) George Smoot and John Mather received the 2006 Nobel Prize for discovering that the cosmic microwave background (CMB) radiation is not isotropic – not completely uniform across the sky. Discuss the significance of this finding in the context of the Big Bang model. [3]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(d) Other than the cosmic microwave background (CMB) radiation, state what other observational evidence supports the Big Bang model. [1]

. . . . . .

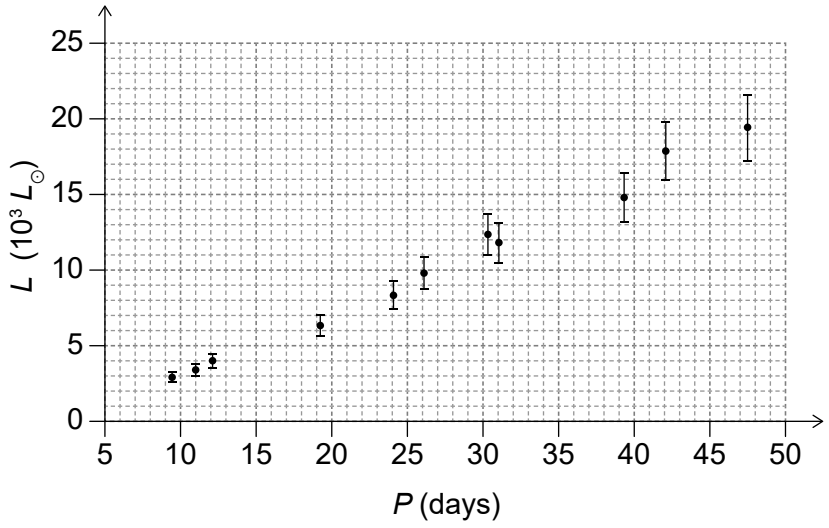
. . . . . .

Section B

Answer **all** questions. Answers must be written within the answer boxes provided.

5. (a) **Graph 1** refers to a selected group of Cepheid variable stars. It shows their luminosity L relative to the solar luminosity $L_\odot$ as a function of their pulsation period P in days. Error bars are shown for the vertical axis only.

Graph 1



(i) Draw a best-fit line through the data. [1]

(ii) Estimate the fractional uncertainty in the luminosity for the star with the longest period. [1]

. . . . . .

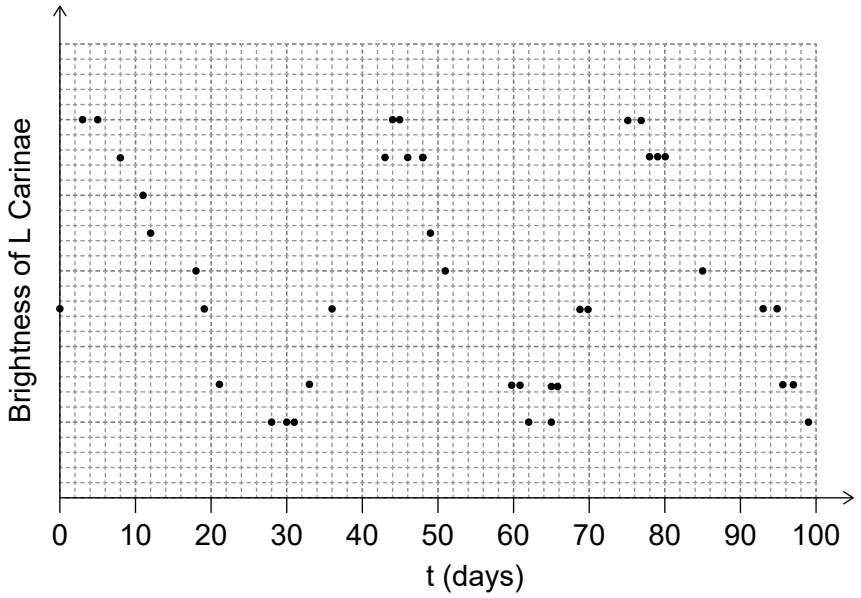
. . . . . .

(This question continues on the following page)

(Question 5 continued)

(b) **Graph 2** shows the light-curve of L Carinae, a Cepheid variable star observed by amateur astronomers from different countries. The vertical axis is proportional to the logarithm of the brightness.

Graph 2



(i) Estimate, by using an appropriate fit line, the period of oscillation of this variable. [2]

. . . . . .

. . . . . .

(ii) Estimate, using **graph 1 and graph 2**, the luminosity of L Carinae. [2]

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 5 continued)

(c) The average temperature of L Carinae is very similar to the temperature of our Sun. Calculate the average diameter of L Carinae in km, assuming it behaves as a black body. [3]

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(d) A more detailed model suggests that the pulsation period of Cepheid variable stars is proportional to $L^{\frac{3}{4}}$. Show that your best-fit line is not consistent with this model. [2]

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(e) The spectral type of L Carinae was observed to change with time. The table shows the spectral type on two different dates. Discuss how the star's spectral lines changed between both dates. [2]

Day	Spectral type
1	F8
5	G2

. . . . . .
. . . . . .
. . . . . .
. . . . . .

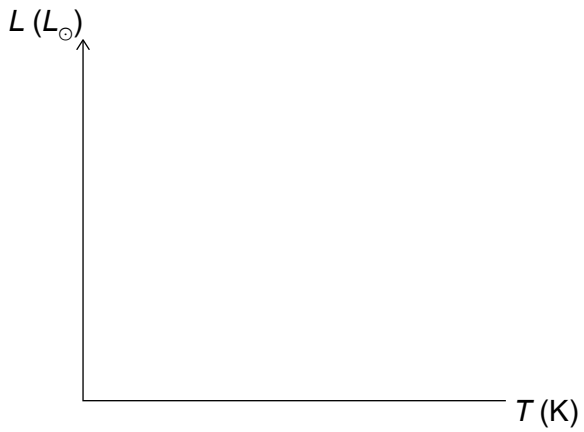
(This question continues on the following page)

(Question 5 continued)

(f) The following data correspond to the star Enif.

Spectral type: K2
Luminosity: $2.5 \times 10^3 L_\odot$
Mass: 12 Ms

(i) Complete the Hertzsprung–Russell (HR) diagram **and** suggest in which region Enif would be located. [3]



(ii) Deduce that Enif spent less time on the main sequence than the Sun. [3]

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(g) State **one** reason why professional astronomers sometimes obtain their data from experienced amateur astronomers. [1]

. . . . . .
. . . . . .

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

Answers written on this page
will not be marked.

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

Answers written on this page
will not be marked.

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

Answers written on this page
will not be marked.