Diploma Programme
Programme du diplôme
Programa del Diploma

# Astronomy
# Standard level
# Paper 2

Friday 3 May 2019 (morning)

Candidate session number

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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]**.

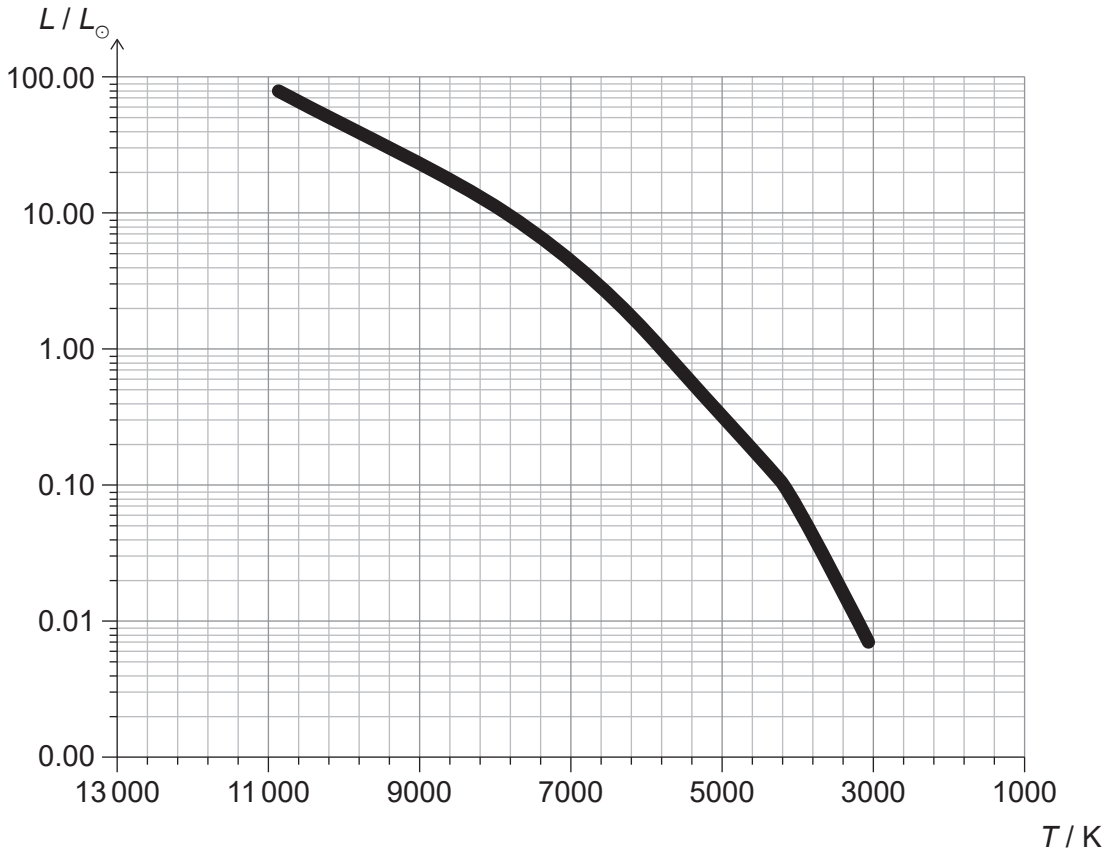


2219 – 9005

## Section A

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

**1.** q Velorum is a main sequence star of 20 $L_\odot$ and spectral type A2. The Hertzsprung–Russell (HR) diagram below shows part of the main sequence.




(a) Estimate the radius of q Velorum, assuming it behaves like a black body. [3]

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**(Question 1 continued)**

(b) Distinguish, with reference to features in their spectra, between a star of spectral type A and one of spectral type M. [1]

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(c) Explain why the spectra of most stars show dark absorption lines against a bright background. [3]

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(d) Outline the next stage in the evolution of q Velorum. [2]

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(e) q Velorum has a mass of about two solar masses. State the kind of object it will become when it dies. [1]

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**2.** (a) The Chicxulub crater in Mexico (Yucatan Peninsula) has been linked to a large meteorite fall 65 million years ago. During the impact about $1 \times 10^{23}$ J were released. The meteorite had an estimated mass of $3 \times 10^{14}$ kg.

(i) Identify **one** possible energy transformation during the impact. [1]

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(ii) Calculate the approximate speed of the asteroid before the impact. [2]

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(b) The Chicxulub impact was a global catastrophe leading to mass extinctions. Explain how the impact led to a mass extinction event. [3]

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**(Question 2 continued)**

(c) Explain how the age of the solar system can be determined from meteorites. [2]

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(d) The Moon shows a far larger number of craters than the Earth. Suggest **two** mechanisms that explain this lack of terrestrial craters. [2]

Mechanism 1: . . . . . .

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Mechanism 2: . . . . . .

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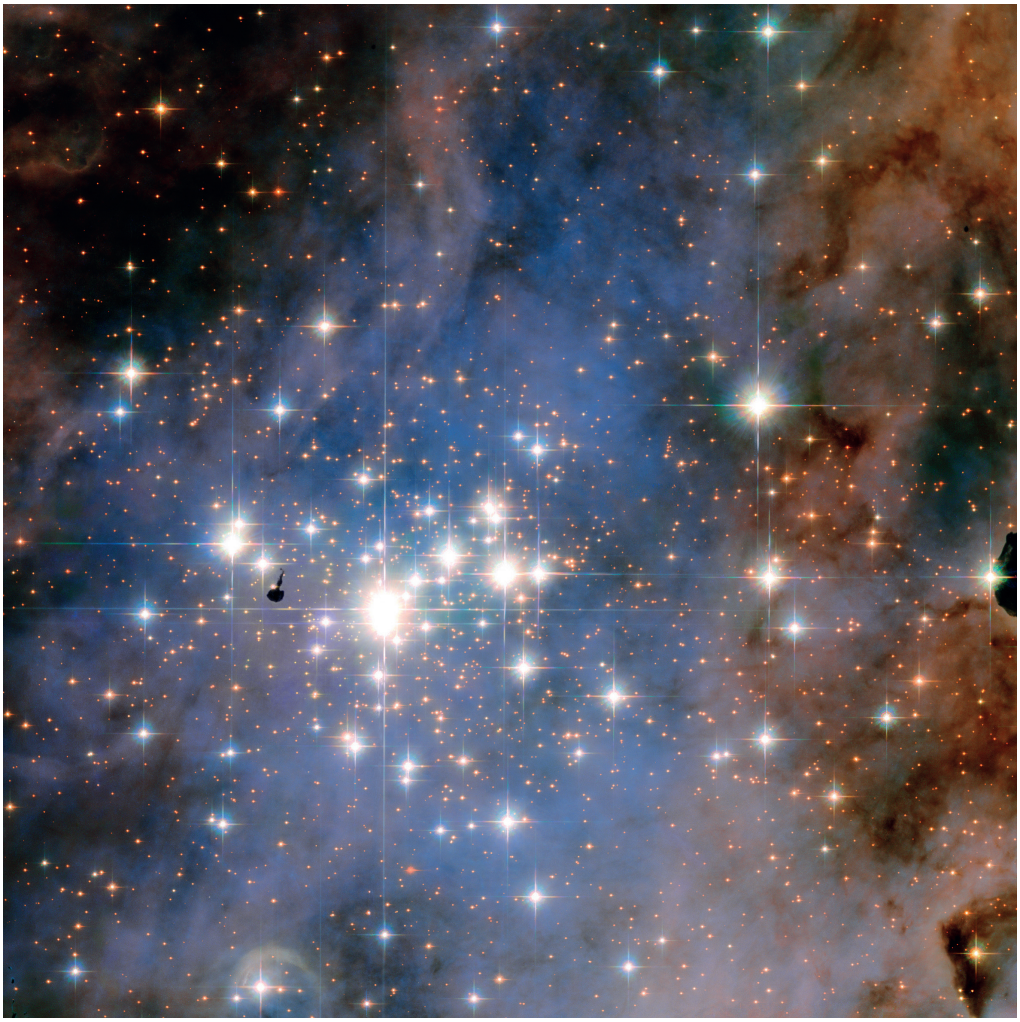
**3.** (a) The image below shows the cluster Trumpler 14 in our galaxy.



[Source: www.jpl.nasa.gov, NASA/STScI]

(i) State which galactic population this cluster belongs to. [1]

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(ii) Distinguish, with reference to their stellar content, between open clusters and globular clusters. [2]

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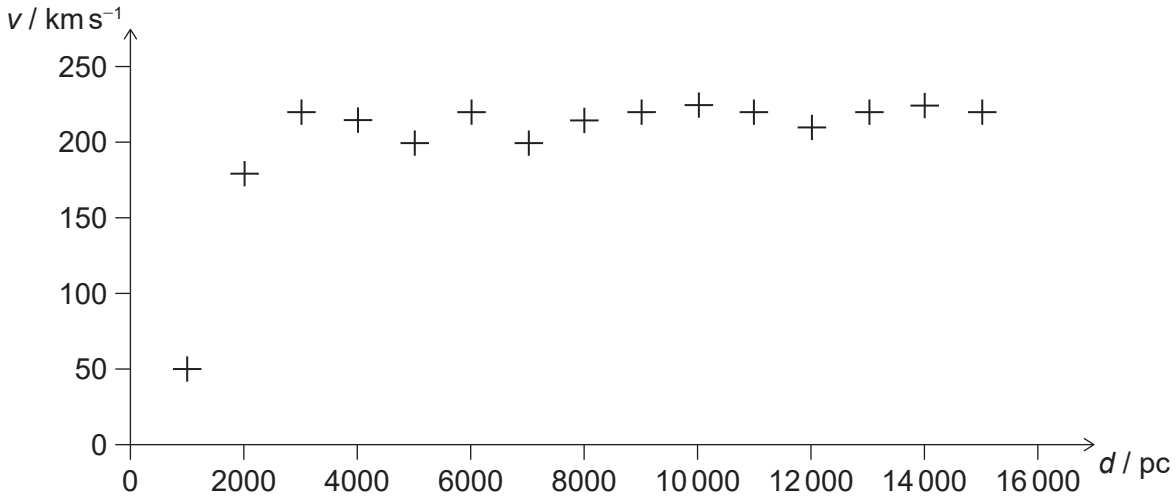
**(Question 3 continued)**

(b) The graph below shows the rotation curve for a galaxy similar to our own.

(i) Sketch the expected trend if the stars moved in Keplerian orbits. [2]




(ii) Show that the observed curve suggests the possible presence of dark matter within the galaxy. [3]

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(c) Outline how the distance to the centre of the Milky Way was determined from observations of globular clusters. [3]

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**4.** (a) Einstein's theory of General Relativity was successfully tested during observations of a solar eclipse. Explain how these observations provided evidence for the theory. [3]

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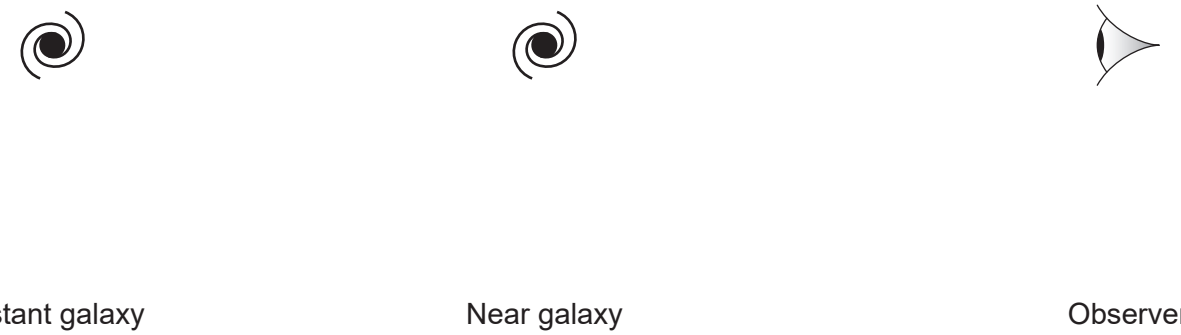
The diagram shows two galaxies, one near the observer and the other farther away. The observer, represented by the eye on the right, sees the results of a gravitational lens.

(b) Draw light rays showing how the gravitational lens is formed. [3]




(c) Early astronomers believed that the universe is uniformly filled with galaxies when very large distances are considered. Identify **one** piece of evidence that contradicts this idea. [1]

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(d) Explain why any observation or image of an astronomical object is from its past. [2]

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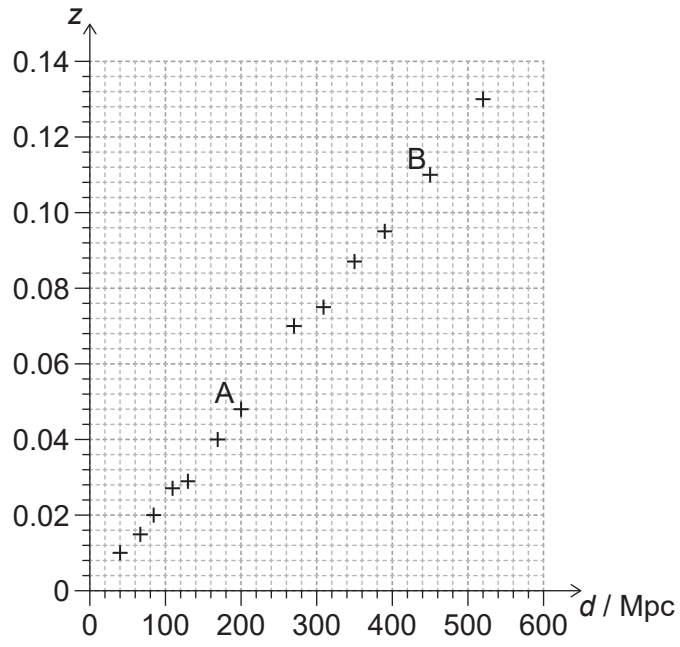
## Section B

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

**5.** (a) The graph below shows measured redshifts *z* of various galaxies as a function of their distances *d*.




(i) Estimate the distance to a galaxy with a radial velocity of $1.8 \times 10^4$ km s$^{-1}$. [3]

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**(Question 5 continued)**

(ii) Explain why galaxies near our Milky Way galaxy may have negative redshifts. [3]

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(iii) Estimate, from the graph, the value of Hubble's constant. [2]

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(iv) The galaxies labelled **A** and **B** on the graph have the same apparent brightness as seen from Earth. Show that the luminosity of **B** is about five times greater than the luminosity of **A**. [4]

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**(Question 5 continued)**

(b) The picture below shows NGC 3982, a galaxy located 21 Mpc from the Sun. The scale of the image is 1.1″/mm (arc-seconds per mm).

[Source: European Space Agency and Stephen Smartt (University of Cambridge)]

(i) Estimate the diameter, in parsecs, of NGC 3982. [3]

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(ii) Determine the Hubble type of NGC 3982. [1]

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**(Question 5 continued)**

(iii) Describe **two** features that helped you to answer the previous question. [2]

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(c) The universe possibly contains billions of galaxies. Discuss how scientists can study the properties of systems when they are so numerous. [2]

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