A

AQA

Surname _____

Forename(s) _____

Centre Number _____

Candidate Number _____

Candidate Signature _____

I declare this is my own work.

A-level

PHYSICS

Paper 3

Section B Astrophysics

7408/3BA

Thursday 15 June 2023 Morning

At the top of the page, write your surname and forename(s), your centre number, your candidate number and add your signature.

[Turn over]

Time allowed: The total time for both sections of this paper is 2 hours. You are advised to spend approximately 50 minutes on this section.

MATERIALS

For this paper you must have:

- **a pencil and a ruler**
- **a scientific calculator**
- **a Data and Formulae Booklet**
- **a protractor.**

INSTRUCTIONS

- **Use black ink or black ball-point pen.**
- **Answer ALL questions.**
- **You must answer the questions in the spaces provided. Do not write on blank pages.**
- **If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).**
- **Do all rough work in this book. Cross through any work you do not want to be marked.**
- **Show all your working.**

INFORMATION

- **The marks for questions are shown in brackets.**
- **The maximum mark for this paper is 35.**
- **You are expected to use a scientific calculator where appropriate.**
- **A Data and Formulae Booklet is provided as a loose insert.**

DO NOT TURN OVER UNTIL TOLD TO DO SO

SECTION B

Answer ALL questions in this section.

0 1 . 1

Draw a labelled diagram to define the parsec (pc).
[1 mark]

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[Turn over]

TABLE 1 shows data for two stars: Rigel and the Sun.

TABLE 1

STAR	SURFACE TEMPERATURE / K	ABSOLUTE MAGNITUDE	MASS / kg
Rigel	12 000	−7.84	3.6×10^{31}
Sun	5700	4.83	2.0×10^{30}

0 1 . 2

State the spectral class of Rigel. [1 mark]

0 1 . 3

The apparent magnitude of Rigel is 0.11

Calculate, in pc, the distance from Rigel to the Earth.
[2 marks]

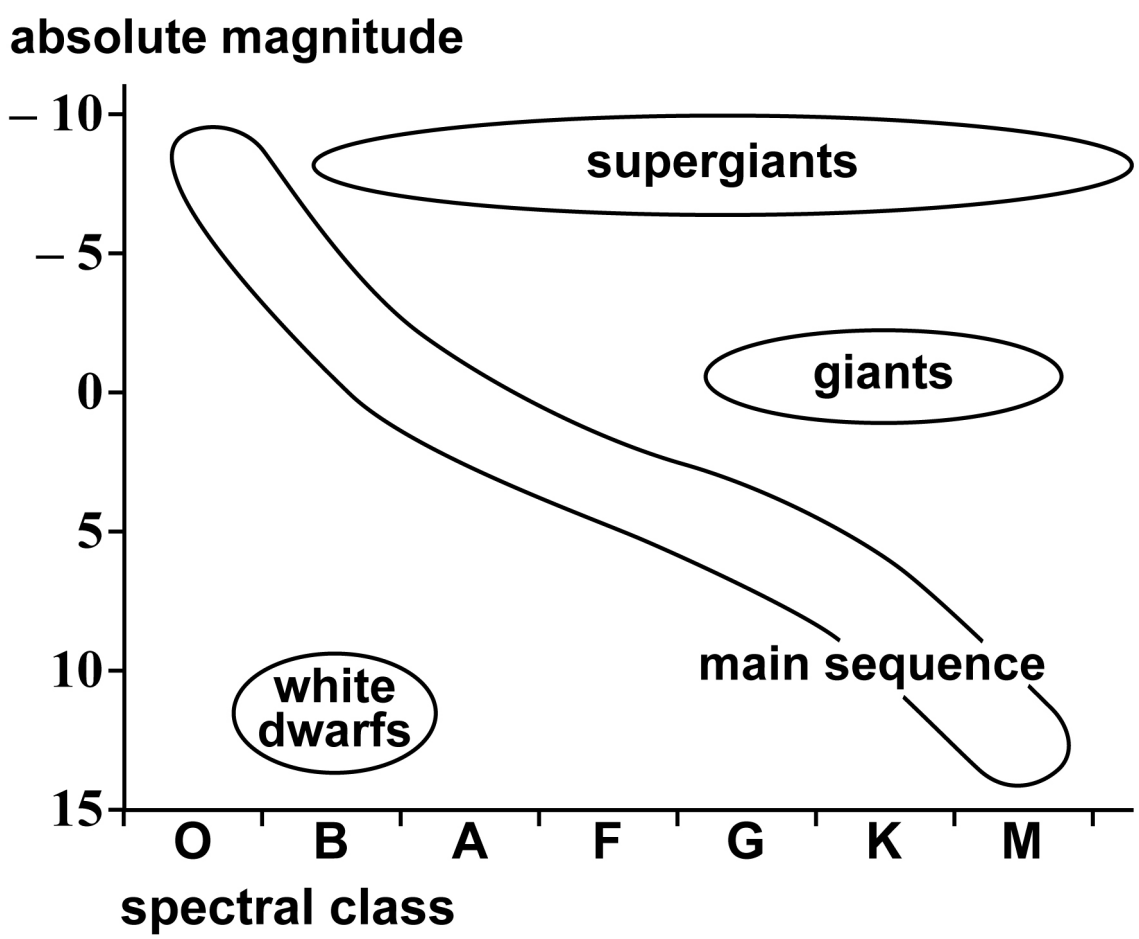
distance = _____ **pc**

[Turn over]

0 1 . 4

FIGURE 1 shows a Hertzsprung–Russell (HR) diagram.

FIGURE 1



Draw a line on FIGURE 1 to show the evolution of the Sun from formation to white dwarf. [1 mark]

0 1 . 5

One stage in the evolution of Rigel includes the emission of a gamma ray burst.

Outline the circumstances during which a gamma ray burst will be emitted by Rigel. [2 marks]

7

0 2 . 1

State what is meant by normal adjustment when applied to an astronomical refracting telescope. [1 mark]

0 2 . 2

Which combination of lenses gives the largest angular magnification when used as an astronomical telescope in normal adjustment?

Tick (✓) ONE box. [1 mark]

	OBJECTIVE LENS		EYEPIECE LENS	
	Focal length / cm	Type	Focal length / cm	Type
☐	5	diverging	100	converging
☐	5	converging	100	converging
☐	100	diverging	5	converging
☐	100	converging	5	converging

V1031 and WASP-82 are two stars in the constellation Orion.

V1031 appears 40 times brighter than WASP-82 when viewed from Earth.

The apparent magnitude of V1031 is 6.0

0 2 . 3

Calculate the apparent magnitude of WASP-82.
[2 marks]

apparent magnitude = _____

0 2 . 4

V1031 is just visible to the naked eye of an astronomer when her pupil diameter is $7\ \text{mm}$.

Suggest whether she can observe WASP-82 using a telescope with an objective diameter of $60\ \text{mm}$.

Support your answer with a calculation. [2 marks]

0 2 . 5

CCDs are often connected to telescopes.

Explain TWO reasons why this improves the ability of astronomers to observe dim stars. [3 marks]

1 _____

_____

_____

_____

_____

_____

2 _____

_____

_____

_____

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_____

_____

9

0 3 . 1

State the defining property of a black hole. [1 mark]

0 3 . 2

In 2019, astronomers linked several radio telescopes to produce a single telescope called the EHT. The resolution of the EHT is the same as the resolution that a telescope with an aperture equal to the diameter of the Earth could achieve.

TABLE 2 shows data about the EHT and the Hubble telescope.

TABLE 2

	APERTURE	OPERATING WAVELENGTH
EHT	1.3×10^7 m	1.3 mm
Hubble	2.4 m	410 nm

Galaxy M87 is 5.3×10^7 light years from Earth. The supermassive black hole at the centre of M87 has a mass 6.5×10^9 times the mass of the Sun.

The radius of the event horizon is R.

The astronomers propose to use either the EHT or the Hubble telescope to observe stars whose distance from the centre of the black hole is less than $1000R$.

Discuss, with calculations, which telescope is more suitable for this observation. [4 marks]

0 3 . 3

A star is orbiting the black hole in M87. The star is observed in the plane of its orbit.

The wavelength of a spectral line observed in the light emitted from the star varies between a maximum and a minimum value.

maximum value observed = 374.96 nm
minimum value observed = 373.53 nm

Calculate the orbital speed of the star. [3 marks]

orbital speed = _____ m s^{-1}

[Turn over]

8

0 4

M40 A and M40 B are two stars that appear very close to each other when viewed from Earth.

There are two possible reasons for this:

- **they are an orbiting binary system**
- **they are distant from each other and only appear in the same line of sight.**

In an orbiting binary system, the difference between the apparent magnitude and the absolute magnitude for each star is similar.

TABLE 3 shows data about these two stars.

TABLE 3

	TEMPERATURE/ K	RADIUS OF STAR / m	APPARENT MAGNITUDE
M40 A	6000	6.3×10^{9}	9.7
M40 B	4700	1.1×10^{10}	10.1

Discuss the appearance of the two stars to an astronomer on the Earth.

In your answer you should:

- **compare the colour of the stars**
- **compare the brightness of the stars**
- **deduce, with a calculation, whether the stars form an orbiting binary system. [6 marks]**

[Turn over]

[Turn over]

6

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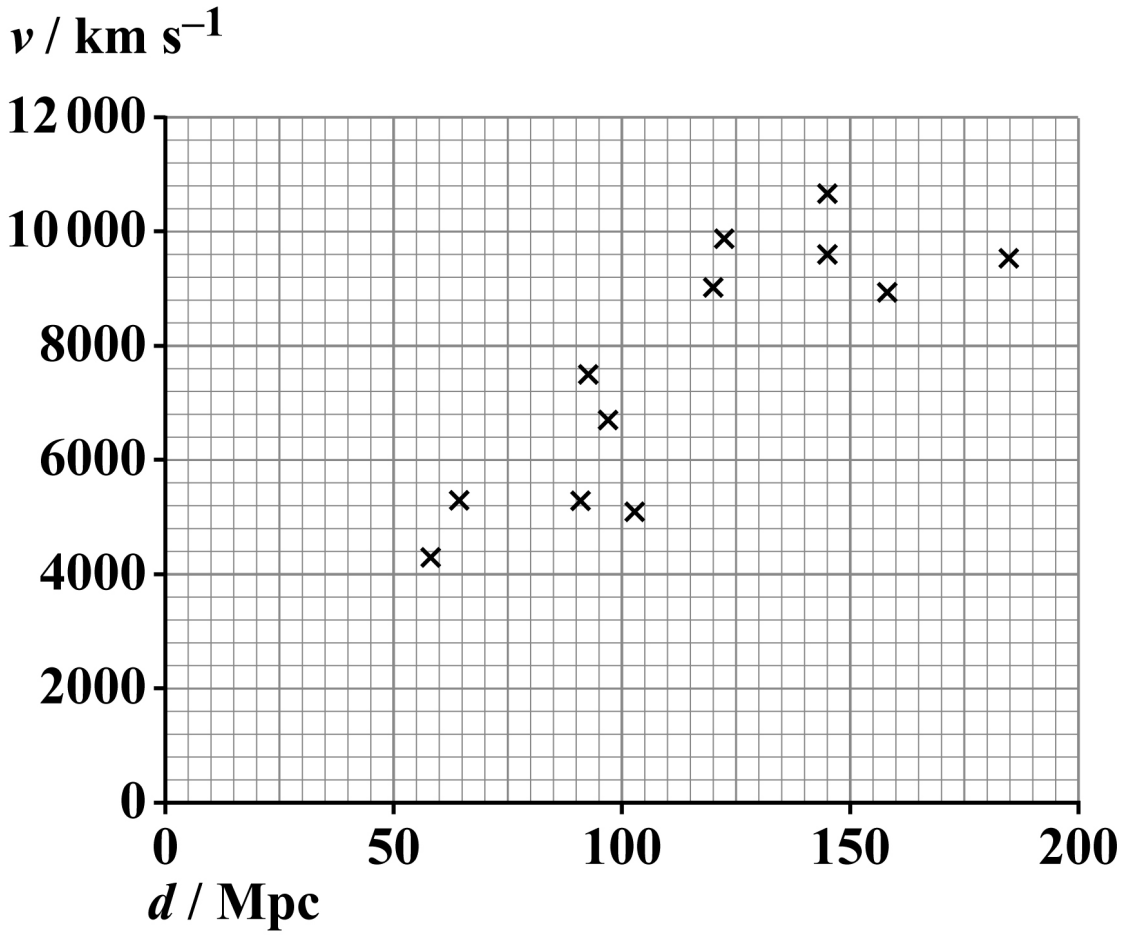
[Turn over]

0 5

FIGURE 2 shows, for some galaxies, how their recession speed v varies with distance d from the Earth.

FIGURE 2



0 5 . 1

Estimate, using FIGURE 2, the age in seconds of the Universe. [3 marks]

age of Universe = _____ s

[Turn over]

0 5 . 2

The estimate in Question 05.1 assumes that the Universe has expanded at a constant rate. Measurements involving type 1a supernovae that are at large distances from Earth caused astronomers to make a modification to this assumption.

State:

- **the modification**
- **the explanation that was proposed to account for this modification.**

[2 marks]

END OF QUESTIONS

5

Additional page, if required.

Write the question numbers in the left-hand margin.

Additional page, if required.

Write the question numbers in the left-hand margin.

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For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	