AQA

Please write clearly in block capitals.

Centre number						Candidate number				

Surname ____________________

Forename(s) ____________________

Candidate signature ____________________

A-level PHYSICS

Paper 3
Section B Astrophysics

Thursday 14 June 2018 Morning

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.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- 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.

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

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Section B

Answer **all** questions in this section.

0 1 The Griffith Observatory in Los Angeles includes an astronomical refracting telescope (Griffith telescope) with an objective lens of diameter 305 mm and focal length 5.03 m

D (lens diameter)

0 1 . 1 Calculate the wavelength of light for which the Griffith telescope has a minimum angular resolution of 1.8×10^{-6} rad

[2 marks]

wavelength — θ (angular resolution)

$\theta = \frac{\lambda}{D}$ $\quad \lambda = \theta D$

$= 1.8 \times 10^{-6} \times 0.305$ ✓ (in metres)

$= 5.5 \times 10^{-7}$ m

wavelength = 5.5×10^{-7} ✓ m

0 1 . 2 The Griffith telescope is used to observe two point objects which subtend an angle of 1.8×10^{-6} rad at the unaided eye.

The typical human eye has a minimum angular resolution of approximately 3.2×10^{-4} rad

Calculate the focal length of the eyepiece lens so that an observer can just resolve the two objects when observing them through the Griffith telescope.

[3 marks]

Focal length = 5.03m

$M = \frac{f_{obj}}{f_{eye}} = \frac{5.03}{f_{eye}}$

$f_{eye} = \frac{5.03}{M}$ ✓ $\quad \left\{ M = \frac{3.2 \times 10^{-4}}{1.8 \times 10^{-6}} \right\}$ ✓

$= \frac{5.03 \times 1.8 \times 10^{-6}}{3.2 \times 10^{-4}} = 0.028$m

focal length = 0.028 ✓ m

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0 1 . 3 The asteroid Apophis has a diameter of 325 m

It has been calculated that, in 2029, its distance of closest approach to the Earth's surface will be 3.0×10^4 km

The Griffith telescope may be used to view Apophis using the eyepiece calculated in question **01.2**

Deduce whether this telescope is suitable to obtain a detailed view of Apophis.
Support your answer with a calculation.

[3 marks]

$\theta = \frac{l}{r}$

$= \frac{325}{3.0\times10^7} = 1.1\times10^{-5}$ rad. ✓

Angular resolution = 1.8×10^{-6} rad.

$\frac{1.1\times10^{-5}}{1.8\times10^{-6}} = 6.11$, so the asteroid's angular diameter is 6.11 times the minimum resolution ✓

You wouldn't be able to see the asteroid in very much detail ✓

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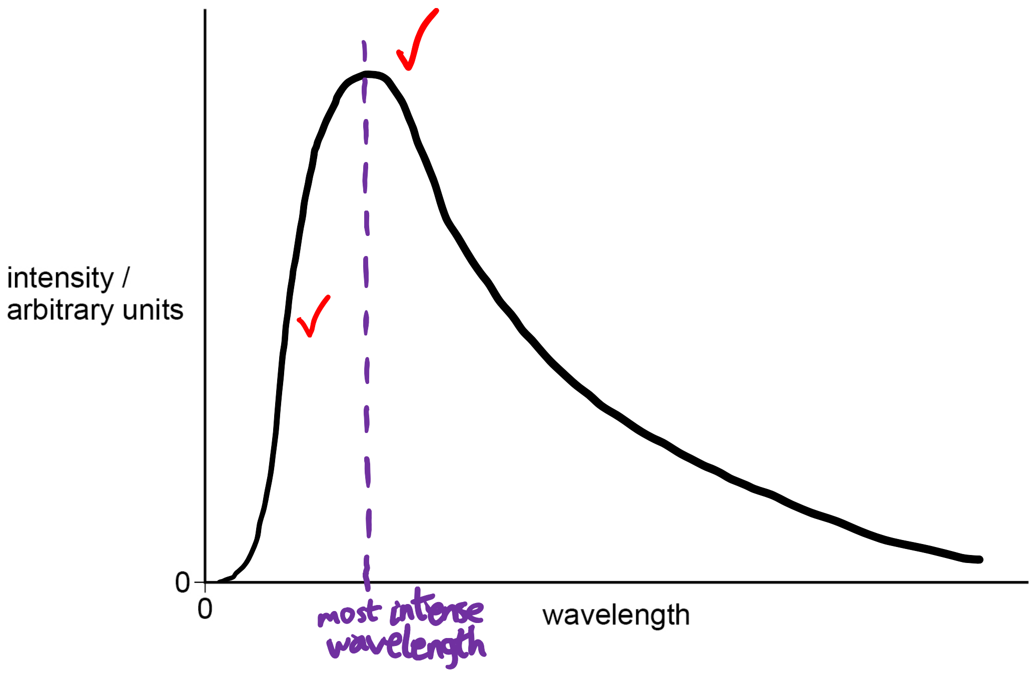
0 2 . 1 Sketch, on the axes in **Figure 1**, the black-body radiation curve for a typical star.

[2 marks]

Figure 1



0 2 . 2 Explain, with reference to the SI units involved, how the curve you have drawn can be used to determine the black-body temperature of the star.

[3 marks]

The peak of the graph is at the peak wavelength, which is the wavelength with the highest intensity. ✓

Use Wien's displacement law, but make sure that wavelengths are in metres. ✓

$$\lambda_{max} = \frac{0.0029 \text{m.K}}{T}$$ ✓

peak wavelength (λ_{max}); temperature in kelvin (T)

Question 2 continues on the next page

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0 2 . 3 Two stars, 61 Cygnus A and 61 Cygnus B, can be seen very close together in the constellation Cygnus. Early astronomers were unsure whether the two stars form a binary system, or simply appear in the same line of sight.
Table 1 shows some of the properties of the two stars.

Table 1

	Temperature / K	Radius / km	Apparent magnitude
61 Cygnus A	4500	4.7×10^5	5.2
61 Cygnus B	4100	4.1×10^5	6.1

Evaluate whether the data support the suggestion that the two stars form a binary system.

In your answer you should

- compare the two stars as seen by an observer on Earth
- support your evaluation with suitable calculations.

[6 marks]

Colour and Brightness

Colour

· Cygnus B is redder than Cygnus A, as it is cooler.
· Cygnus B will therefore have a shorter peak wavelength.

Brightness

There is a difference in apparent magnitude of 0.9 $(= 6.1 - 5.2) = \Delta m$

Ratio of brightness $= 2.51^{(\Delta m)} = 2.51^{0.9} = 2.3$

Cygnus A's brightness will appear to be roughly double Cygnus B's brightness

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Distance

$P = \sigma A T^4$ (power; stefan constant, $5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$; surface area; surface temperature in kelvin)

$P_A = 5.67 \times 10^{-8} \times 4\pi \times (4.7 \times 10^8)^2 \times 4500^4$
$= 6.45 \times 10^{25}\ W$

$P_B = 5.67 \times 10^{-8} \times 4\pi \times (4.1 \times 10^8)^2 \times 4100^4$
$= 3.38 \times 10^{25}\ W$

If Cygnus A is roughly twice as powerful, and appears twice as bright, there are no variations caused by a difference in distance, so the stars must be approximately the same distance away.

Evaluation

If the stars are close in a constellation and at the same distance, it is likely that they form a binary star system.

0 2 . 4 What is the spectral class of 61 Cygnus A?
Tick (✓) the correct box.

[1 mark]

A ☐

F ☐

G ☐

K ☑ 3700K ↔ 5200K

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0 3 . 1 Describe the links between galaxies, black holes and quasars.

[2 marks]

• Quasars are produced by black holes. ✓

• These black holes are at the centres of galaxies. ✓

0 3 . 2 At a distance of 5.81×10^8 light year, Markarian-231 is the closest known quasar to the Earth. The red shift z of Markarian-231 is 0.0415

Use these data to estimate an age, in seconds, of the Universe.

[4 marks]

Age of Universe $= \frac{1}{H_0}$ — Hubble constant

$z = \frac{v}{c}$ (v: recession velocity; c: speed of light)

$v = H_0 d$ (d: distance)

$H_0 = \frac{v}{d} = \frac{zc}{d}$ ✓

Age of Universe $= \frac{1}{H_0}$ ✓ $= \frac{d}{zc} = \frac{5.81\times10^8 \times 3\times10^8 \times 365\times24\times3600}{0.0415 \times 3\times10^8}$ ✓ (1 ly in metres)

$= \frac{5.81\times10^8 \times 365\times24\times3600}{0.0415} = 4.415\times10^{17}$ s

age = 4.42×10^{17} ✓ s

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0 3 . 3 A typical quasar is believed to be approximately the size of the solar system, with a power output similar to that of a thousand galaxies.

Estimate, with reference to the inverse-square law, how much further the most distant visible quasar is likely to be compared to the most distant visible galaxy.

[3 marks]

• Both are at the limits of our vision/ measurement, so the power received from either will be the same ✓

• Intensity of quasar = intensity of galaxy

$$\frac{P_{quasar}}{d_{quasar}^2} = \frac{P_{galaxy}}{d_{galaxy}^2} \checkmark$$

$$\frac{1000}{d_{quasar}^2} = \frac{1}{1^2}$$ {Using multiples of galaxy power and distance}

$d_{quasar} = 1000^{1/2} = 31.6 \times d_{galaxy}$ ✓

Turn over for the next question

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0 4 Evidence to support the Big Bang theory comes from cosmological microwave background radiation and the relative abundance of hydrogen and helium in the Universe.

0 4 . 1 Explain what is meant by cosmological microwave background radiation and how its existence supports the Big Bang theory.

[3 marks]

- The cosmological microwave background radiation comes from all areas of the Universe rather than a specific location. ✓
- When the Universe cooled enough, matter and radiation were able to decouple. Protons and electrons were able to join together to form neutral atoms. ✓
- As the Universe expanded, the radiation was red-shifted (its wavelength became larger) into the microwave region of the electromagnetic spectrum. ✓

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0 4 . 2 Explain how the relative abundance of hydrogen and helium supports the Big Bang theory.

[3 marks]

- Shortly after the Big Bang, temperatures were high enough to fuse hydrogen to helium. ✓
- When the Universe expanded and cooled enough, this fusion stopped. ✓
- Hydrogen : helium ratio was left at 3:1, and temperatures were no longer high enough to fuse either of these elements into heavier ones, altering the ratio further. ✓

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END OF QUESTIONS

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