Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

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

General Certificate of Education
Advanced Level Examination
June 2013

Physics A PHYA5/2A

Unit 5A Astrophysics
Section B

Thursday 20 June 2013 9.00 am to 10.45 am

For this paper you must have:
- a calculator
- a ruler
- a Data and Formulae Booklet (enclosed).

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 50 minutes on this section.

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 section is 35.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

Do not write outside the box

Section B

The maximum mark for this section is 35. You are advised to spend approximately 50 minutes on this section.

1 (a) Draw a ray diagram to show how a converging lens can be used to form a diminished image of a real object. Label the object, image and principal foci of the lens on your diagram.

(3 marks)

1 (b) A student experimented with a converging lens whose focal length was known to be approximately 50 cm. She placed an object and screen a fixed distance of 200 cm apart. With the lens 128 cm from the object, she observed a sharp image on the screen.

Calculate the focal length of the lens.

focal length ..... cm

(2 marks)

Do not write outside the box

1 (c) The lens was used as one of the components of a simple refracting astronomical telescope. State whether the lens formed the eyepiece or objective, giving reasons for your answer.

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(2 marks)

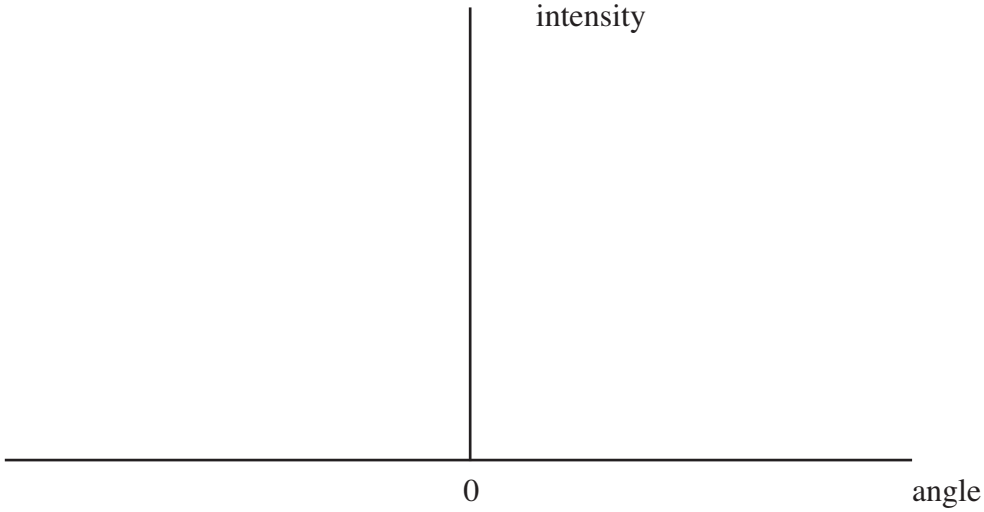
7

Turn over for the next question

Do not write outside the box

2 There is a supermassive black hole at the centre of the Milky Way galaxy. It is difficult to resolve images of the region around this black hole directly.

2 (a) (i) Sketch, on the axes, the variation in intensity of the diffraction pattern produced when light from a point object passes through a circular aperture.



(2 marks)

2 (a) (ii) The *Rayleigh criterion* is used to determine the smallest angular separation between two point objects which can be resolved by a telescope. With reference to the diffraction patterns formed, explain what is meant by the Rayleigh criterion. You may draw a diagram to aid your explanation.

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(2 marks)

Do not write outside the box

2 (b) The supermassive black hole at the centre of the Milky Way galaxy has a mass equal to 4.1 million solar masses.
Calculate the Schwarzschild radius, R_s, for this black hole.
Give your answer to an appropriate number of significant figures.

R_s ..... m
(3 marks)

2 (c) Astronomers investigating the supermassive black hole at the centre of the Milky Way galaxy detect radio waves at a frequency of 230 GHz. By correlating the information from several radio telescopes, they can obtain images with the same resolution as a single radio telescope with a diameter of 5000 km.

2 (c) (i) Calculate the minimum angular separation which could be resolved by a radio telescope of diameter 5000 km detecting waves of frequency 230 GHz.

angular separation ..... rad
(2 marks)

2 (c) (ii) The centre of the Milky Way galaxy is 25 000 light years from the Earth.

Show that the limit of the resolution of the telescope is approximately five times the angle subtended by the Schwarzschild radius of the black hole at this distance.

(2 marks)

11

Do not write outside the box

3 Many astronomical observations rely on a Charge Coupled Device (CCD) to obtain an image. Describe the structure and operation of the CCD and discuss the advantages of using a CCD for astronomical observations.

The quality of your written communication will be assessed in this question.

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(6 marks)

6

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4 (a) The table summarises some of the properties of two stars in the constellation of Ursa Minor.

name	apparent magnitude	radius of star / radius of the Sun	spectral class
Polaris	2.0	50	F
Kocab	2.0	50	K

4 (a) (i) Using these data, describe and explain **one** similarity and **one** difference in the appearance of the two stars as seen with the unaided eye by an observer on the Earth.

similarity .....

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difference .....

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(2 marks)

4 (a) (ii) Deduce which of the two stars is further from the Earth.

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(3 marks)

Question 4 continues on the next page

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4 (b) Ursa Minor also contains the galaxy NGC 6251. Measurements indicate that the light from the galaxy has a red shift, z, of 0.025 and that the galaxy is 340 million light years from Earth.

4 (b) (i) Use these data to calculate a value for the Hubble constant.

value ..... $km\,s^{-1}\,Mpc^{-1}$

(3 marks)

4 (b) (ii) Use your answer to part (b)(i) to estimate a value for the age of the Universe. State an appropriate unit for your answer.

age ..... unit .....

(3 marks)

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END OF QUESTIONS

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