

AQA A-LEVEL PHYSICS

PHYSICS



EXAM QUESTION PACK

UNIT 5A ASTROPHYSICS OLD SPECIFICATION PAPERS

STEMUP

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Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

Forename(s)

Candidate signature

A-level PHYSICS A

Unit 5A Astrophysics
Section B

Tuesday 28 June 2016

Morning

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.

Materials

For this paper you must have:

- a calculator
- a pencil and a ruler
- a Data and Formulae Booklet (enclosed).

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.



Section B

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

- 1** A converging lens of focal length 0.15 m is used as the eyepiece of an astronomical refracting telescope in normal adjustment.

- 1 (a)** The angular magnification of the telescope is 5.0

Calculate the distance between the eyepiece lens and the objective lens of the telescope.

[3 marks]

distance = _____ m

- 1 (b)** A student measures the focal length of the eyepiece lens. She uses it to form an inverted, magnified image of a real object.

- 1 (b) (i)** State **one** other property of the image formed by the lens.

[1 mark]

- 1 (b) (ii)** The image is formed 0.60 m from the lens.
Calculate the object distance.

[2 marks]

object distance = _____ m



- 1 (b) (iii)** Draw a labelled ray diagram to show how the image is formed.
A scale diagram is **not** required.

[3 marks]

- 1 (c)** Further analysis of the lens reveals that the value of its focal length depends on the wavelength of the light used.

What is the name given to the image problem associated with this variation of focal length?

Place a tick (✓) in the right-hand column to show the correct answer.

[1 mark]

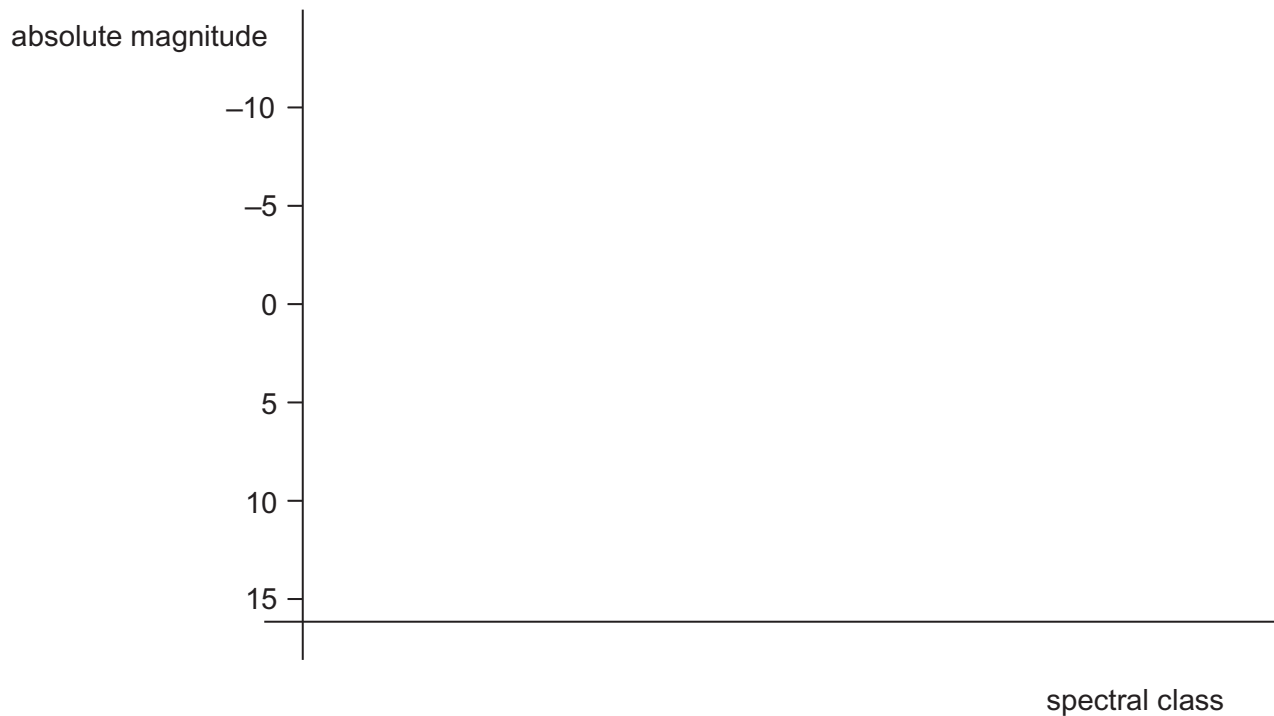
	✓ if correct
Rayleigh criterion	
Quantum efficiency	
Chromatic aberration	
Spherical aberration	

Turn over ►



- 2 (a)** **Figure 1** shows the axes of a Hertzsprung–Russell (H–R) diagram.

Figure 1



- 2 (a) (i)** Label the spectral class axis with a suitable scale.

[1 mark]

- 2 (a) (ii)** Complete the H–R diagram by marking the positions of the main sequence, dwarf star and giant star regions.

[2 marks]

- 2 (b)** **Table 1** summarises some of the properties of three stars in the constellation Aries.

Table 1

Star	Apparent magnitude	Temperature / K	Radius / m
Hamal	2.0	4 500	1.0×10^{10}
Sharatan	2.7	9 000	1.8×10^9
41 Arietis	3.6	12 000	9.6×10^{10}



- the appearance to the naked eye of the three stars as seen from Earth
- the spectrum of the three stars
- the region of the Hertzsprung–Russell diagram to which each star belongs.

[6 marks]

[illegible]

Turn over ►



- 2 (b) (ii)** Hamal is 66 light years from the Earth.
Calculate the absolute magnitude of Hamal.

[3 marks]

absolute magnitude = _____

- 2 (b) (iii)** Identify which star is the greatest distance from Earth.
Explain your answer.

[3 marks]



3 A charge coupled device (CCD) can be used to capture the image formed by a telescope.

3 (a) Describe the structure of the part of the CCD where the image is formed.

[2 marks]

3 (b) Explain how a CCD builds up a charge pattern that depends on the image formed on it.

[3 marks]

Turn over for the next question

5

Turn over ►



- 4 (a)** State which property of the first identified quasar led to its discovery.

[1 mark]

- 4 (b)** 3C48 is a quasar in the constellation Triangulum. It is believed to have a power output 4×10^{11} times greater than that of the Sun. At the Earth, the Sun's intensity is 1.4×10^{17} times greater than that of the quasar.

- 4 (b) (i)** Calculate, using the inverse square law, the distance from Earth to this quasar in AU.

[3 marks]

distance = _____ AU

- 4 (b) (ii)** Measurements of the red shift of the quasar suggest the expansion of the Universe has accelerated since the detected light left the quasar.
State the cause of this acceleration.

[1 mark]

END OF QUESTIONS

5



A-level Physics

PHYA5/2A – Astrophysics
Mark scheme

2450
June 2016

Version: 1.0 Final

Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

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Further copies of this mark scheme are available from aqa.org.uk

Question	Answers	Additional Comments/Guidance	Mark	ID details
1 (a)	Use of $M = f_o/f_e$ To give $5 = f_o/0.15$ ✓ And $f_o = 0.75\text{m}$ Use of length = $f_o + f_e$ ✓ To give length = $0.75 + 0.15 = 0.9(0)\text{(m)}$ ✓	The first mark is for substitution into the magnification equation. If $M=50$ used allow max 2. If f_o and f_e are reversed, allow max 1. The second mark is for using the sum of the focal lengths. If f_o-f_e used allow max 1. The third mark is for the final answer. Allow c.e. for the second and third marks.	3	
1 (b) (i)	real	Allow "not virtual" Allow "can be captured on a screen" or similar	1	
1 (b) (ii)	Use of $1/f = 1/u + 1/v$ To give $1/0.15 = 1/u + 1/0.6$ ✓ And therefore $u = 0.2(0)\text{ m}$ ✓	There is no c.e. for using a negative value of image distance or focal length If f_o used for f_e allow max 1 If 0.9 m used for f_e , give 0/2 If correct answer seen without substitution, give 2/2. Condone use of u for image distance and v for object distance.	2	
1 (b) (iii)	Ray diagram: One construction ray correct, ✓	If telescope seen, only first mark can be awarded.	3	

	Second construction ray correct to give magnified inverted image. ✓ Image, object and focal point labelled. ✓	For fat lens, construction ray must pass through principal axis within the lens. If magnifying glass seen, only 1st and 3rd marks can be awarded. Allow F or labelled focal length. Focal point must be on the side of the lens where the ray cuts the principal axis. Labelled lines for image and object – may be dotted.		
1 (c)	Chromatic aberration		1	
Total			10	
Question	Answers	Additional Comments/Guidance	Mark	ID details
2 (a) (i)	Spectral class axis correct: OBAFGKM ✓	Ignore bunching of labels. Do not condone letters beyond O and M	1	
2 (a) (ii)	Main sequence correct ✓ Dwarf and giant stars correct ✓	Bands not lines. Main sequence must have correct curvature LHS must be above -5 and RHS below 10 on abs mag scale. Dwarfs in bottom left quadrant, below abs mag 5, not touch Main sequence.	2	

		Giants in top right quadrant, can extend left, above abs mag 0, not touch Main sequence.		
2 (b) (i)	Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response. Examiners should apply a 'best-fit' approach to the marking. The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidates answer should be assessed holistically. The answer will be assigned to one of 3 levels according to the following general criteria:			
	Low level (1 or 2 marks)	Intermediate Level (3 or 4 marks)	Higher Level (5 or 6 marks)	
	The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. Appearance: The apparent magnitude scale is identified as the one that indicates brightness, but it may be interpreted the wrong way round by the student. Incorrectly, there may be some reference to how big the stars appear based on the radius. References to colour may be missing altogether Spectrum: little or no relevant detail related to the spectrum of each star is given. Position: on the HR diagram: there may be no attempt.	The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. Appearance: Student gives a coherent description the relative brightness and of the three stars, linked to their apparent magnitude. Spectrum: There may be some less accurate comparison of colour based on temperature or description of the spectra of the stars. Position: There is some attempt to discuss the position of the stars on the HR diagram.	The information conveyed by the answer is clearly organised, logical and coherent using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. Appearance: Student gives a coherent description the relative brightness and of the three stars, linked to their apparent magnitude. For 6 marks, they go on to describe the colour of each star related to the temperature and spectral class Spectrum: The student further describes the spectrum of each of the three stars in terms of the major absorption lines, again related to the spectral class from their temperatures. Position on HR. There is some discussion of the position of the stars. For example it is pointed out that 41	

			Arieti cannot be a dwarf star as it is too large.			
	Summary of relevant information about each star				extra information Answers that suggest that the size of the stars can be compared visually are unlikely to be awarded marks in the top half of a band.	
	Property	41 Arieti	Sharatan	Hamal		
	Brightness	Dimmest	Middle	Brightest		
	Colour	Blue	Blue/ white	Orange/ red		
	Spectra	He and H	H and ionised metals	Neutral metals		
	class	B	A	K		
	type of star	Main sequence Not dwarf.	Main sequence	Main sequence		
	Position on HR	Top left	Middle/ left	Middle/ Right		
2 (b) (ii)	d = 66 /3.26 = 20 pc ✓ Use of m-M = 5 log (d/10) To give 2 – M = 5 log (20/10) ✓ M = 2 – 1.5 = 0.5 ✓			The first mark is for the conversion of d into parsec Allow ce for two marks. If M and m wrong way round, treat as physics error: only the first mark can be awarded The second mark is the correct substitution	3	

		The third mark is for the final answer; allow 0.46 to 0.5; no sf penalty		
2 (b) (iii)	41 Arietis has the largest radius and temperature, ✓ and therefore the greatest power output/ brightest abs mag/greatest intrinsic brightness (ref to $P = \sigma AT^4$) ✓ But appears dimmest in the sky (as it has the greatest apparent magnitude.) so 41 Arietis must be furthest away. ✓	No mark for an unsupported answer. Allow area for radius The first two marks can be awarded for a correct calculation of the power of 41 Arietis.	3	
Total			15	

Question	Answers	Additional Comments/Guidance	Mark	ID details
3 (a)	A silicon chip ✓ (divided into)picture elements ✓	Condone silicone, but not silicon(e) dioxide etc. Ignore references to wiring or process Allow pixels for picture elements	2	
3 (b)	The image formed on the CCD is created by incident photons. These photons cause <u>electrons</u> to be released. ✓ The electrons are trapped in (“potential wells” in the CCD) ✓ The number of electrons liberated (in each pixel) is proportional to the intensity of the light/number of photons falling (on each pixel). or so that the pattern of the charge built up is related to the image. ✓	The first mark is for identifying the role of photons in forming the charge build up. Condone excited/promoted Do not condone ejected/emitted/escaped. References to the photoelectric effect loses the first mark. The second is for describing how the charge /no of electrons is stored/built up The third is for stating the relationship between the number of electrons/charge and the image pattern.	3	
Total			5	

Question	Answers	Additional Comments/Guidance	Mark	ID details
4 (a)	The quasar is a <u>bright</u> radio source.✓	Allow strong/intense/powerful for bright. Ignore reference to pulses Other incorrect properties, eg red shift, loses the mark.	1	
4 (b) (i)	Using $I = I_0/d^2$ with some evidence of substitution ✓ $P_q = 4 \times 10^{11} P_s$ $I_s = 1.4 \times 10^{17} I_q$ at Earth $P_s/1^2 = 1.4 \times 10^{17} (4 \times 10^{11} P_s/d^2)$ ✓ $d^2 = 4 \times 10^{11} \times 1.4 \times 10^{17}$ $= 5.6 \times 10^{28}$ $d = 2.4 \times 10^{14} \text{ AU}$ ✓	The first mark is for some evidence of using the inverse square law. Do not condone equation the wrong way up. The second is for an attempt to compare the two stars using the inverse square law. The third is for the final answer.	3	
4 (b) (ii)	Dark energy	Evidence of hedging bets eg dark energy/dark matter etc. loses the mark	1	
Total			5	

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 2015

Physics A

PHYA5/2AR

Unit 5A Astrophysics
Section B

Thursday 18 June 2015 9.00 am to 10.45 am

For this paper you must have:

- a calculator
- a pencil and 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.
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Information

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- The maximum mark for this section is 35.
- You are expected to use a calculator where appropriate.
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 - use good English
 - organise information clearly
 - use specialist vocabulary where appropriate.



J U N 1 5 P H Y A 5 2 A R 0 1

G/ME/Jun15/PHYA5/2AR/E1

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PHYA5/2AR

Section B

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

- 1 (a)** **Table 1** summarises some of the properties of Vesta, one of the largest objects in the asteroid belt between Mars and Jupiter.

Table 1

Diameter / m	Distance from the Sun / AU	
	smallest	largest
5.4×10^5	2.15	2.57

- 1 (a) (i)** Calculate the largest possible distance, in m, between the Earth and Vesta.

[2 marks]

distance = ... m

- 1 (a) (ii)** Show that when Vesta is at a distance of 1.73×10^{11} m from Earth, the angle subtended by Vesta to an observer on Earth is about 3×10^{-6} radian.

[2 marks]

1 (b) Observations of Vesta have been made by the Infrared Telescope Facility (IRTF) in Hawaii.

1 (b) (i) Draw a ray diagram for a Cassegrain telescope.

[2 marks]

1 (b) (ii) The IRTF includes a camera capable of detecting infrared radiation with wavelengths in the range $1.0\ \mu\text{m}$ to $5.0\ \mu\text{m}$.

The smallest angle the telescope can resolve is 3.3×10^{-7} radian.

Calculate the diameter of the objective of the telescope.
Give your answer to a suitable number of significant figures.

[2 marks]

diameter of objective = ... m

Question 1 continues on the next page

Turn over ►



- 1 (c)** Discuss the level of detail the IRTF would be able to detect on the surface of Vesta, when Vesta is 1.73×10^{11} m from Earth.

[2 marks]

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10



Turn over for the next question

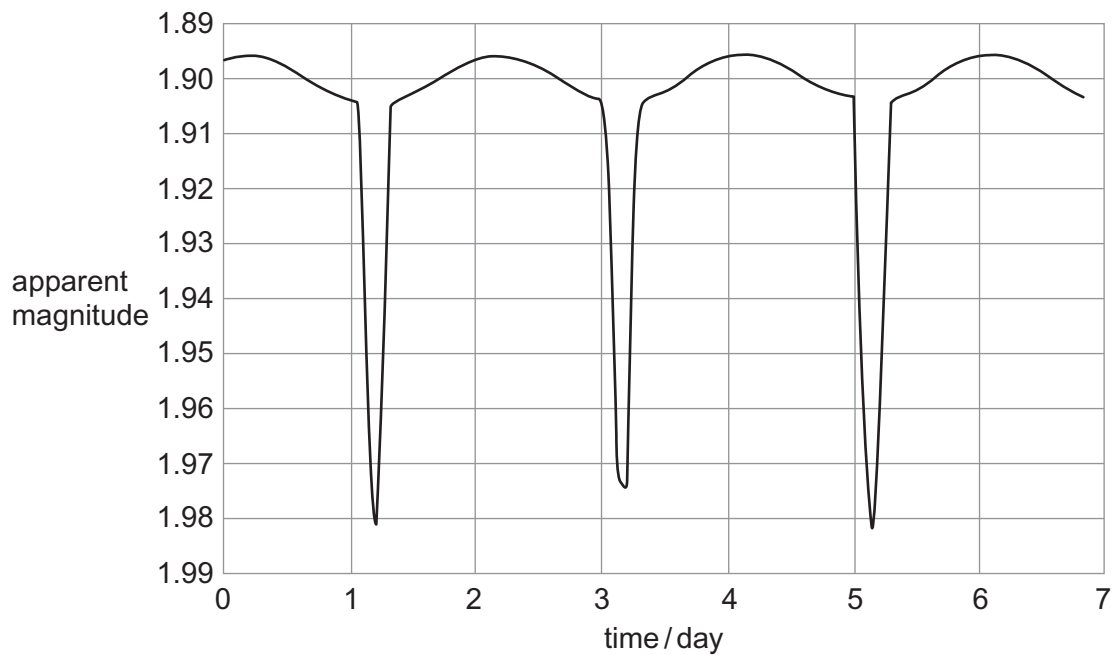
**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**

Turn over ►



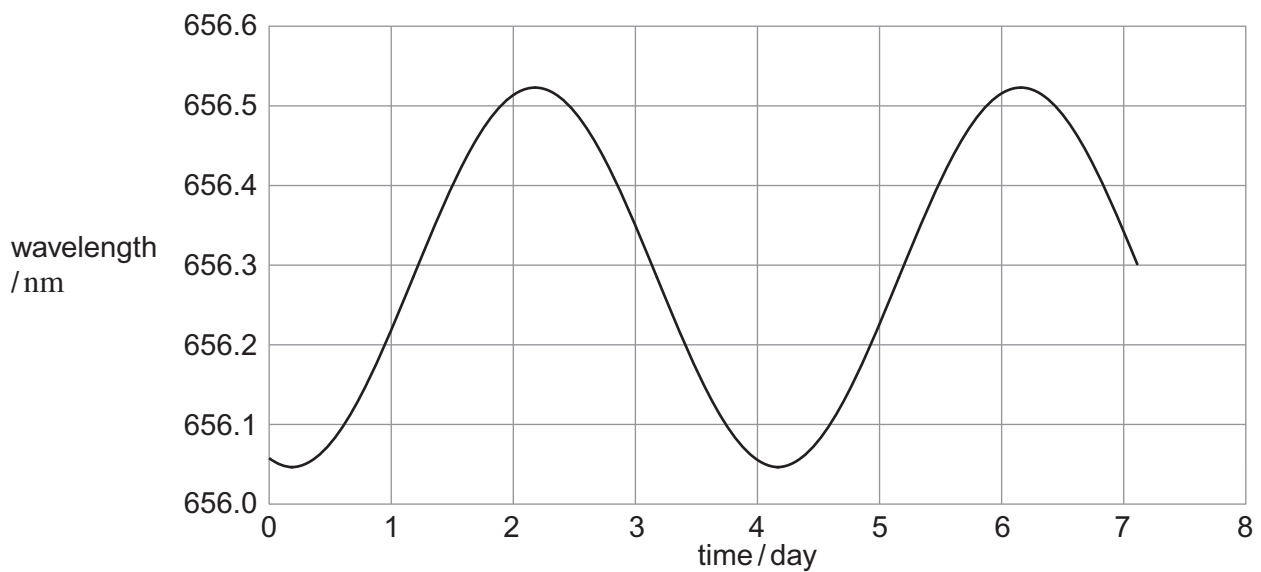
- 2 Menkalinan is an eclipsing binary star system in the constellation of Auriga. **Figure 1** shows the variation in apparent magnitude with time (light curve) for Menkalinan.

Figure 1



Analysis of the spectrum of one of the stars shows a periodic variation in wavelength. **Figure 2** shows the results for one of the spectral lines in the Hydrogen Balmer series. The wavelength for this line as measured for a source in a laboratory on the Earth is 656.28 nm.

Figure 2



The quality of your written communication will be assessed in your answer.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Turn over ►



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2 (b) The black body temperature of each star is approximately 9200 K.

Explain why a Hydrogen Balmer line was chosen for the analysis of wavelength variation.

[2 marks]

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2 (c) The distance from the Earth to Menkalinan is 7.7×10^{17} m.

Calculate the value of the absolute magnitude of Menkalinan when it appears dimmest.

[3 marks]

absolute magnitude = ...

11

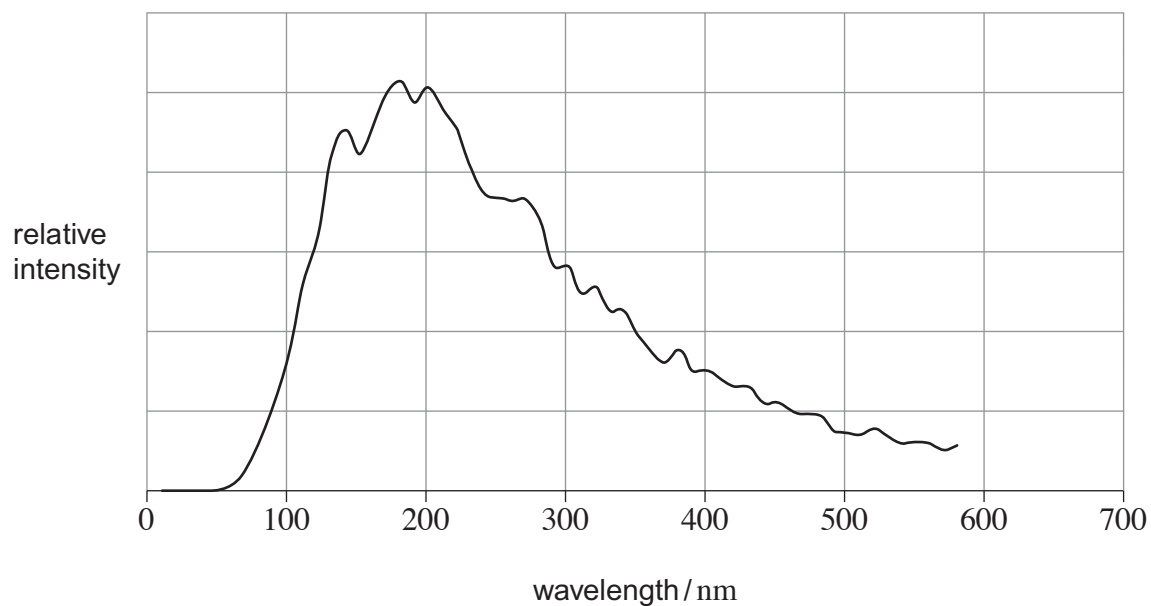
Turn over for the next question

Turn over ►



3 **Figure 3** shows the variation of intensity with wavelength for the star 40 Eridani B.

Figure 3



3 (a) (i) Calculate the black body temperature of 40 Eridani B.

State an appropriate unit for your answer.

[3 marks]

temperature = ... unit



3 (a) (ii) 40 Eridani B has a total power output of 4.2×10^{24} W.

Calculate its radius.

[2 marks]

radius = ... m

3 (b) (i) Which of the following regions of the Hertzsprung-Russell diagram does 40 Eridani B belong to?

Tick (✓) the correct answer.

[1 mark]

main sequence	
dwarf star	
giant star	

3 (b) (ii) Give reasons for your answer to part (b)(i).

[2 marks]

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.....

.....

8

Turn over for the next question

Turn over ►



4 NGC 3842 is a galaxy which contains one of the biggest black holes ever discovered.

4 (a) State what is meant by a black hole.

[1 mark]

.....

.....

.....

4 (b) The mass of the black hole in NGC 3842 is believed to be 1.0×10^{10} times greater than that of the Sun.

Calculate the radius of its event horizon.

[2 marks]

radius = ... m

4 (c) NGC 3842 is 3.3×10^8 light years from the Earth, and is receding at a velocity of $6.3 \times 10^6 \text{ m s}^{-1}$.

Estimate, using these data, an age in seconds for the Universe.

[3 marks]

age of Universe = ... s

END OF QUESTIONS



A-LEVEL

Physics

PHYA5/2AR – Astrophysics

Mark scheme

2450

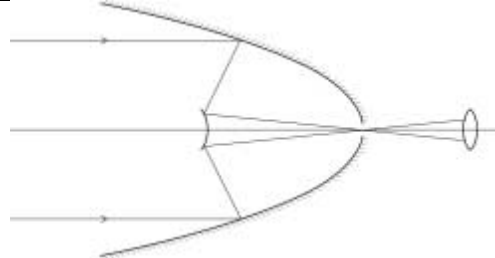
June 2015

Version 1: Final mark scheme

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Question	Answers	Additional Comments/Guidance	Mark	ID details
1 (a) (i)	largest distance = $2.57 + 1 = 3.57 \text{ AU}$ ✓ $3.57 \text{ AU} = 3.57 \times 1.5 \times 10^{11} \text{ m}$ $= 5.36 \times 10^{11} \text{ (m)}$ ✓	The first mark is for the correct distance in AU The second mark is for the correct conversion to metres. Allow c.e.	2	
1(a) (ii)	angle = s/r $= 5.4 \times 10^5 / 1.73 \times 10^{11}$ ✓ $= 3.12 \times 10^{-6} \text{ (rad)}$ ✓	Working needs to be shown for the first mark. At least two sf needed for final mark.	2	
1 (b) (i)	mirrors correct ✓ primary concave, secondary convex. No shading needed. Primary mirror should be continuous i.e. not two mirrors If no hole, evidence can be given by rays passing through rays correct ✓ rays must cross after the secondary mirror	 The lens does not need to be included	2	

1 (b) (ii)	angular resolution = λ / D $D = 1 \times 10^{-6} / 3.3 \times 10^{-7} \checkmark$ $D = 3.0 \text{ m}$ 2 sf needed $\checkmark$	Allow use of factor of 1.22 Allow 1 sf if justified by discussion of approximate nature of calculation.	2	
1 (c)	Minimum angular resolution is better/smaller than the size of the asteroid. $\checkmark$ Details of about 1/10 the angular size of Vesta/ 50km can be seen. $\checkmark$	The first mark is for qualitative comparison, the second for the quantitative analysis.	2	
Total			10	

Question				ID details
2 (a)	Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response. Examiners should also refer to the information on page 4 and apply a ‘best-fit’ approach to the marking. The candidate’s writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidates answer should be assessed holistically. The answer will be assigned to one of 3 levels according to the following criteria:			
0 marks	Level 1 (1-2 marks)	Level 2 (3-4 marks)	Level 3 (5-6) marks	
	Lower level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. Calculations: No relevant calculations. At 1 mark the time period may be quoted as 2 days rather than four. Discussion Only one graph discussed (or both very poorly).	Intermediate level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and no fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. Calculations: Some attempt to use Doppler equation. At four marks there may be only a couple of minor errors. Discussion: Correctly links at least one graph to the	High level (good to excellent): 5 or 6 marks. The information conveyed by the answer is clearly organised, logical and coherent using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. Calculations: Doppler equation applied correctly. (perhaps a minor error at 5 marks) At the highest level, the use of 4 days and velocity to give the radius may be seen. Discussion:	

	At 1 mark there may some attempt to discuss eclipsing or going towards/away. At 2 marks one discussion will be more correct.	movement of the two stars in terms of eclipsing or movement relative to each other and the Earth.	2 graphs discussed. Mostly correct. At 5 marks there may be some minor incorrect statements – eg referring to red shift rather than Doppler shift.	
	Examples of the points made in the response The explanations expected in a good answer should include most of the following physics ideas The time period , T, is the time from the first dip in the light curve to the third dip. (I) This is approximately 4 days (L) This is one full cycle for the wavelength graph.(I) One full cycle is approximately 4 days.(I) When one star passes in front of the other the amount of light received changes. (L) The brightest (lowest value of) apparent magnitude occurs when both stars can be seen. (I) The dips occur when one star is in front of the other. (I) The similarity in the dips suggests that both stars have similar temperatures/sizes (H) The variation in wavelength is due to the Doppler effect. (I) The peaks and troughs occur when the stars are moving at their greatest velocity away from / towards us.(H) The biggest change in wavelength is $656.52 \text{ nm} - 656.28 \text{ nm} = 0.24 \text{ nm}$ (I)		extra information The letter next to each statement suggests the minimum level of answer the statement may be seen in.	

	The orbital speed, v , is therefore $\Delta\lambda \times c / \lambda$ (I) $= 0.24 \times 3 \times 10^8 / 656.28 = 1.1 \times 10^5 \text{ ms}^{-1}(\text{H})$ The orbital radius is therefore $v / (2\pi/T) = 6.1 \times 10^9 \text{ m (H)}$			
2(b)	The temperature (9200K) indicates that the star is in spectral class A. ✓ Hydrogen Balmer lines are strongest in A class stars and therefore would be more easily measured. ✓	Reference to class A not essential if it is clear that stars contain hydrogen in $n=2$ state.	2	
2 (c)	$m - M = 5 \log (d/10)$ $d \text{ (in parsec)} = 7.7 \times 10^{17} / 3.08 \times 10^{16} = 25 \text{ pc}$ ✓ dimmest $m = 1.981$ ✓ $\text{dimmest } M = 1.981 - 5 \log(25/10)$ $= -0.009$ ✓	Allow range 1.980 to 1.982 for m Allow c.e. for either d or m . If both incorrect, no marks are awarded.	3	
Total			11	

Question	Answers	Additional Comments/Guidance	Mark	ID details
3 (a) (i)	$\lambda_{\text{max}} T = 0.0029$ $\lambda_{\text{max}} = 180 \times 10^{-9} \text{ m}$ ✓	Allow range for wavelength 170nm to 190nm correct 150nm to 200nm incorrect but treat as a.e. Anything else treat as PE –first two marks not	3	

	$T = 0.0029/180 \times 10^{-9}$ $= 1.6 \times 10^4$ ✓ K ✓	awarded. Allow kelvin for unit. But not degrees kelvin.		
3(a) (ii)	$P = \sigma AT^4$ $A = P/\sigma T^4 = 4.2 \times 10^{24} / (5.67 \times 10^{-8} \times (1.6 \times 10^4)^4)$ ✓ $= 1.1 \times 10^{15} \text{ m}^2$ $r = \sqrt{(A/4\pi)} = 9.5 \times 10^6 \text{ m}$ ✓	Allow c.e. for T from ai If formula wrong treat as PE – no marks awarded. Note: this is true if the incorrect equation for A is used within the power equation.	2	
3(b) (i)	dwarf ticked		1	
3(b) (ii)	It has a high temperature ✓ But is relatively small, so it will have a low absolute magnitude ✓ (This puts it into the bottom left region of the HR diagram)	Allow low power output for small. Allow high power output for large Marks can be awarded for ruling out other two. If white dwarf not ticked in bi :- Giant stars – cool and big Main sequence – either cool and small or hot and big for 2 marks Or 'middling temperature and size' for 1 mark	2	
Total			8	
Question	Answers	Additional Comments/Guidance	Mark	ID details
4 (a)	An object with an escape velocity greater than the speed of light ✓	Ignore references to singularity and density etc. Allow gravity so strong light cannot escape	1	
4 (b)	Mass of black hole = $1 \times 10^{10} \times 1.99 \times 10^{30} = 2 \times 10^{40} \text{ kg}$ ✓	M correct for the first mark	2	

	Use of $R = 2GM/c^2$ $= 2 \times 6.67 \times 10^{-11} \times 2 \times 10^{40} / (3.00 \times 10^8)^2$ $= 3 \times 10^{13} \text{ m}$ ✓ allow 2.9 or 2.95 etc	Final answer correct for the second mark. Allow ce for the mass No sf penalty		
4 (c)	$V = Hd$ $v \text{ (in kms}^{-1}\text{)} = 6300$ $D \text{ (in MPc)} = 3.3 \times 10^8 / 3.26 \times 10^6$ $= 101$ ✓ $H = v/d = 6300 / 101 = 62 \text{ kms}^{-1} \text{ Mpc}^{-1}$ ✓ Age of Universe $= 1/H$ $= 1/62$ $= 1.6 \times 10^{-2} \text{ Mpc s km}^{-1}$ $= 1.6 \times 10^{-2} \times 3.1 \times 10^{16} \times 10^6 / 10^3$ $= 5.0 \times 10^{17} \text{ s}$ ✓	Alternatively Age of universe $= 1/H$ $= D/v$ $= 3.3 \times 10^8 \times 9.47 \times 10^{15} / 6.3 \times 10^6$ ✓ $= 5.0 \times 10^{17} \text{ s}$ ✓ The first mark is for calculating D, the second for substituting correctly to find H The third is for determining 1/H in seconds. If other value of H used, 1 mark max.	3	
Total			6	

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 2014

Physics A

PHYA5/2A

Unit 5A Astrophysics Section B

Thursday 19 June 2014 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.



J U N 1 4 P H Y A 5 2 A 0 1

WMP/Jun14/PHYA5/2A/E6

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PHYA5/2A

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 for an astronomical refracting telescope in normal adjustment. Your diagram should show the paths of **three** non-axial rays passing through both lenses. Label the principal foci of the two lenses.

[3 marks]

- 1 (b)** The Treptow Giant Telescope in Berlin is the longest moveable refracting telescope on Earth. Some of its properties are summarised below:

distance between the objective lens and eyepiece lens = 21 m

angular magnification = 210

objective lens diameter = 0.68 m

- 1 (b) (i)** Calculate the focal lengths of the eyepiece lens and objective lens of the Treptow Giant Telescope.

[2 marks]

eyepiece lens focal length m

objective lens focal length m



- 1 (b) (ii)** Early telescopes had very small diameter objective lenses. State **two** advantages of using an astronomical telescope that has a large diameter objective lens when making observations.

[2 marks]

Advantage 1.....

.....

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Advantage 2.....

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- 1 (c)** The images formed by refracting telescopes can suffer from chromatic aberration.

Draw a labelled diagram to show how a converging lens causes chromatic aberration.

[1 mark]



2 The term Big Bang was first used in 1949 by the astronomer Fred Hoyle to refer to, what was then, a controversial theory describing the formation of the Universe.

2 (a) Explain what is meant by the Big Bang theory.

Your answer should include:

- a description of the main aspects of the theory
- an explanation of the different pieces of evidence that support the theory.

The quality of written communication will be assessed as part of your answer.

[6 marks]

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2 (b) A more recent discovery is the acceleration in the expansion of the Universe. Evidence for this acceleration comes from the use of type 1a supernovae as standard candles.

2 (b) (i) State what is meant by a standard candle.

[1 mark]

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2 (b) (ii) Explain how measurements of a type 1a supernova can be used to determine how far away it is from the Earth.

[3 marks]

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10

Turn over ►



3 (a) Define the term absolute magnitude.

[1 mark]

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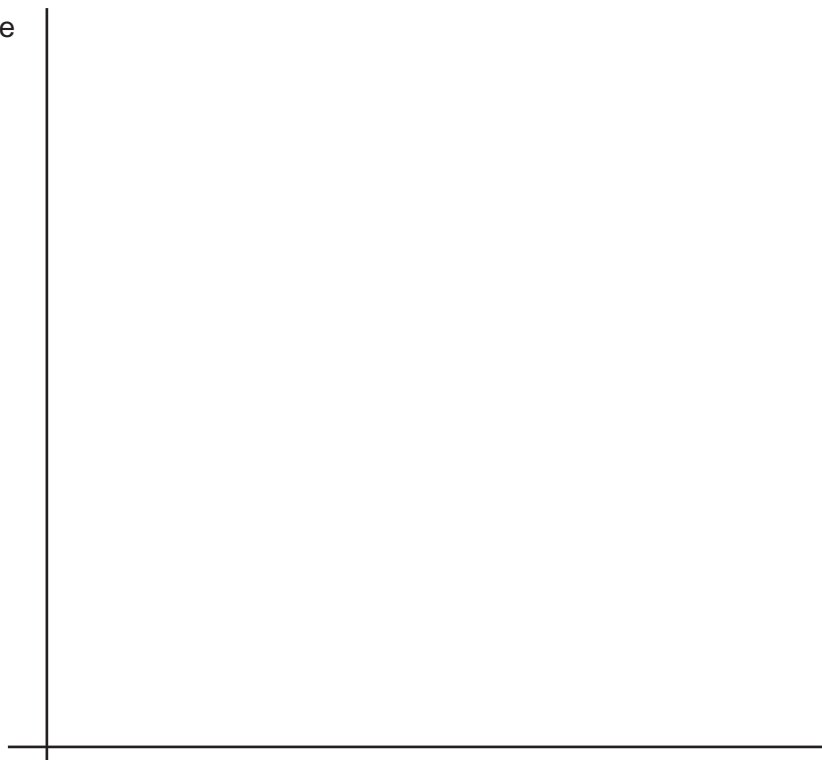
3 (b) **Figure 1** shows the axes of a Hertzsprung-Russell diagram.

Mark suitable scales on the absolute magnitude and temperature axes.

[2 marks]

Figure 1

absolute magnitude



temperature / K



3 (c) Label a possible position of each of the following stars on **Figure 1**:

3 (c) (i) the Sun

[1 mark]

3 (c) (ii) star W, which has the same intrinsic brightness as the Sun, but has a significantly higher temperature

[1 mark]

3 (c) (iii) star X, which has a similar spectrum to the Sun, but is significantly larger

[1 mark]

3 (c) (iv) star Y, which is significantly larger than the Sun and has prominent absorption lines of neutral atoms and titanium oxide (TiO) in its spectrum.

[1 mark]

3 (d) How does the diameter of star W, in part 3(c)(ii), compare with the diameter of the Sun? Explain your answer.

[3 marks]

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10

Turn over for the next question

Turn over ►



- 4 (a)** Explain what is meant by a parsec. Draw a labelled diagram in support of your answer.

[2 marks]

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- 4 (b)** The Hipparcos satellite used the parallax method to measure the distance to more than 100 000 stars with a precision of 0.002 arc seconds. Calculate, in metres, the maximum distance measurable by Hipparcos. Give your answer to an appropriate number of significant figures.

[3 marks]

distance m



- 4 (c)** The star Alpha Capricorni is in fact two stars that appear very close together. Some data about the two stars are summarised in **Table 1**.

Table 1

Star	Distance / pc	Apparent magnitude	Class
Alpha-1 capricorni	211	4.3	G
Alpha-2 capricorni	33	3.6	G

- 4 (c) (i)** Explain how data in the table indicate that the two stars are **not** part of a binary system.

[1 mark]

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- 4 (c) (ii)** Explain why the angular separation of the two stars changes when observed from the Earth during a 12 month period.

[1 mark]

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END OF QUESTIONS

7

Turn over ►



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A-LEVEL PHYSICS A

PHYA5/2A: Astrophysics
Mark scheme

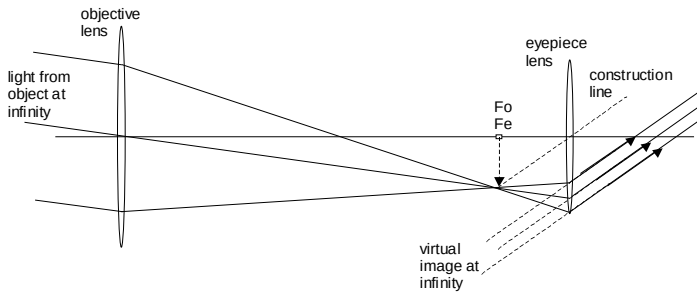
2450
June 2014

Version: 1.0 Final

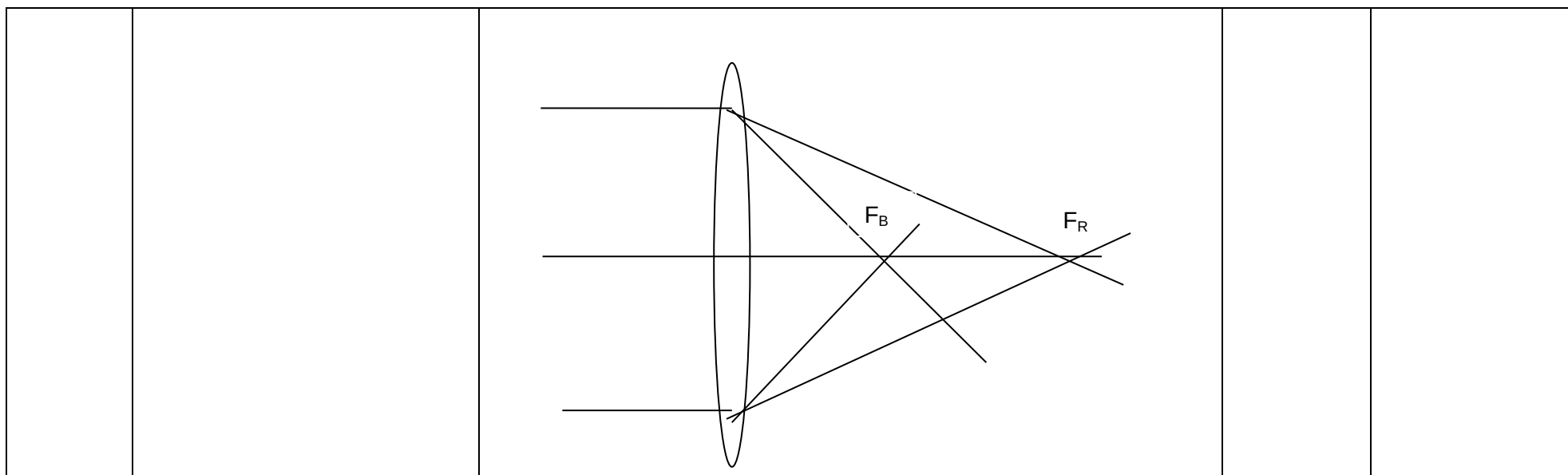
Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

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Further copies of this Mark Scheme are available from aqa.org.uk

Question	Answers	Additional Comments/Guidance	Mark	ID details
1(a)	Both focal points labelled, on the principal axis, and coincide, with $f_o > f_e$ ✓ Three <u>off-axis</u> rays through objective lens correct ✓ Three rays through eyepiece correct, parallel to a construction line. ✓	Accept point or length labelled. Allow single point F. Ignore labels outside the space between the two lenses. Rays must be off-axis to get the second mark. Construction line does not need to be drawn. If only 2 rays drawn, or there is no principal axis, max 2. 	3	
1(b)(i)	Using $f_o + f_e = 21$	Evidence of both equations needed for the mark.		

	$f_o/f_e = 210$ ✓ Gives $211 f_e = 21$ $f_e = 21/211 = 0.10 \text{ m}$ and $f_o = 21 \text{ m}$ (20.9) ✓	Alternative: $f_o = 4410/211 = 0.10 \text{ m}$ If 210 used rather than 211 in substitution, max 1. If the correct answer is obtained by inspection, max 1.	2	
1(b)(ii)	Large diameter allows fainter objects to be viewed, (as the collecting power is proportional to d^2) ✓ Larger diameter allows better resolution(as smallest resolvable angle is proportional to $1/d$)✓	Allow: more light, better collecting power, brighter image, able to see more distant objects (not just further) Allow references to more detail or clearer images for this mark. Ignore references to magnification or field of vision.	2	
1(c)	Diagram showing two focal points with blue focal point closer to lens than red focal p ^{oint} .	Colours must be labelled. Allow wavelengths or frequencies if correct way round Rays need to be focused Allow 1 ray for each colour if principal axis drawn and foci labelled. If other colours included, they must be correct. Allow violet for blue Incident rays do not need to be parallel to the principal axis.	1	



2 (a)			6
Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response. Examiners should also refer to the information on page 4 and apply a 'best-fit' approach to the marking. The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidates answer should be assessed holistically. The answer will be assigned to one of 3 levels according to the following criteria.			
0 marks	Level 1 (1–2 marks)	Level 2 (3–4 marks)	Level 3 (5–6 marks)
	Lower level (Poor to limited): 1 or 2 marks The information conveyed by	Intermediate level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be	High level (good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent using appropriate

	the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate may not explain what the Big Bang theory is. They may only refer to one piece of evidence that supports the theory.	less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate may only refer to two pieces of supporting evidence poorly or one in detail and the description of the big bang theory may be less complete.	specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate describes the big bang theory as the Universe expanding from an extremely dense and hot point over the past 13.6 billion years. The candidate also describes the evidence from, the relative abundances of H and He and the measurement of the microwave background radiation and states they support the big bang theory. Hubble's Law may also be used to support the idea that the Universe is expanding.
examples of the points made in the response The explanations expected in a good answer should include most of the following physics ideas 1 The universe has expanded from a single hot dense point 1 This expansion started approximately 13 billion years ago. 1 Evidence comes from the Hubble relationship and observations of the red shift of distant galaxies. 2 This shows that the galaxies are moving outwards from a single common point. 2 (Conclusive) evidence comes from the cosmological microwave background radiation (which disproved the steady state	extra information The number next to each statement suggests the minimum level of answer the statement may be seen in.		

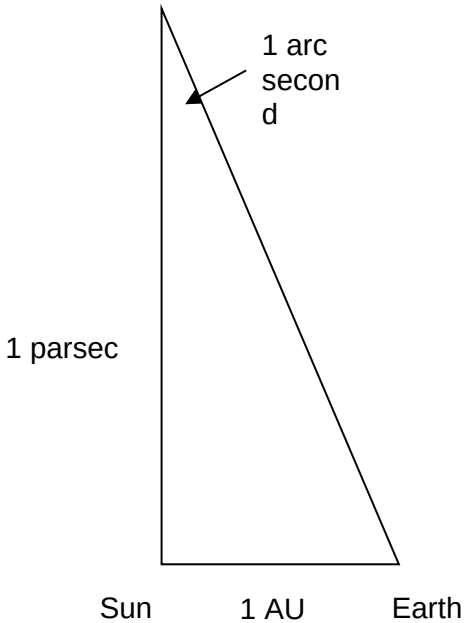
theory) 3 This follows a black body radiation curve which corresponds to a temperature of 2.7 K 3 This can be interpreted as the left over “heat” of the big bang, Hydrogen and helium is present in the Universe in the ratio 3:1 3 This supports the idea that a very brief period of fusion occurred when the Universe was very young, which is consistent with the Big Bang theory.	
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2 (b)(i)	A standard candle is an object whose absolute magnitude <u>is known</u> . ✓	Do not allow “brightness” for absolute magnitude but allow “intrinsic brightness”. Do not allow “constant” for “known”	1	
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2 (b) (ii)	All type 1a supernovae have same <u>peak</u> absolute magnitude Apparent magnitude can be measured (at this peak). ref to $m-M = 5 \log (d/10)$ or inverse square law	The measurement of the apparent magnitude may only be implied and still get credit Alternative using the inverse square law: All type 1a supernova have some peak intensity, I_0 Intensity at Earth can be measured, I Distance, d , can be calculated using $I = I_0/d^2$ If there is no reference to the peak,	3	
------------	---	---	---	--

		max 2.		
3 (a)	Apparent magnitude at a distance of 10pc	Allow “brightness” Do not allow luminosity or magnitude.	1	
3 (b)	Absolute magnitude from 15 to -10 Temperature from 50 000K to 2500K	Allow 15 to -15 Allow 50 000 to 3500 K	2	
3 (c) (i)	S at 5700 K and abs mag 5	The position of S should be consistent with the scales on the axes. Allow ce on scale Allow 6000 for T If labels not present, or if only correct extreme values on scale, S should be to the right of and below the centre.	1	
3 (c)(ii)	W at same abs mag as S, but further to left	Judgements on 3cii – 3civ should be based on the position of S. If S is not labelled, it should be based on where S should be.	1	
3 (c)(iii)	X at same temperature as S but greater absolute magnitude		1	
3 (c)(iv)	Y at same abs mag or above S, on the right hand side of the diagram,		1	
3 (d)	similar power output✓, but is hotter✓ Ref to $P = \sigma AT^4$ hence W must have smaller diameter than the Sun ✓	Allow luminosity for Power Answer must be supported to get the	3	

		mark.		
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4(a)	Diagram showing Earth, Sun and star, with 1AU clearly marked, and 1 arc second angle at the star, with distance between Sun and star as one parsec.  1 pc is the distance at which 1AU subtends an angle of 1 arc second.	A diagram with fewer labels can be supported by a correct statement If either the angle or base are incorrect, 1 max. Right angle does not need to be at the Sun. Triangle does not need to be a right angle Parsec could be the hypotenuse. Ignore writing if the diagram is correct. Base can be either Sun Earth, or 1AU. No diagram, 1 max.	2	
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4 (b)	$d = 1/p$			
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	$= 1/0.002$ parsec $= 500$ pc✓ $= 500 \times 3.1 \times 10^{16}$ m $= 2 \times 10^{19}$ m✓ 1sf✓	Allow ce for d in pc. If $\tan(0.002/3600) = 1\text{AU}/d$ used, allow ce for wrong value of 1AU. Allow use of tan or sin.	3	
4 (c)(i)	Two components are 178 pc apart or Distance apart too great (for gravity to have any significant effect between them)	Penalise attempts to hedge bets by references to apparent magnitude or class.	1	
4 (c)(ii)	More distant star will not appear to move as much as nearest star (against the fixed background)	Allow discussions involving parallax. Give credit to correct diagram.	1	

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.



J U N 1 3 P H Y A 5 2 A 0 1

WMP/Jun13/PHYA5/2A

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PHYA5/2A

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)



- 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

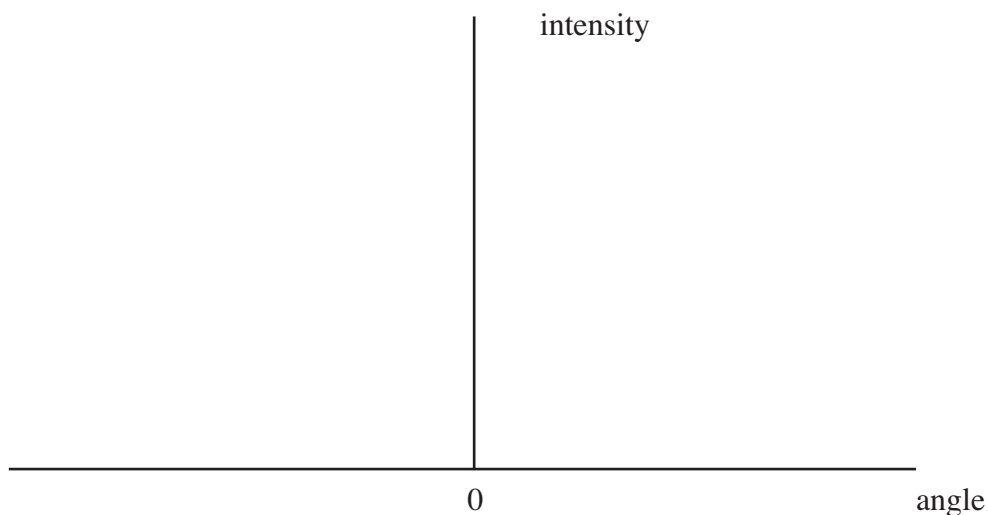
Turn over for the next question

Turn over ►



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)



- 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

Turn over ►



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

[illegible]

6



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

name	apparent magnitude	$\frac{\text{radius of star}}{\text{radius of the Sun}}$	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

Turn over ►



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 $\text{km s}^{-1} \text{Mpc}^{-1}$
(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)

11

END OF QUESTIONS





General Certificate of Education (A-level)
June 2013

Physics A

PHA5A

(Specification 2450)

Unit 5A: Nuclear and Thermal Physics

Astrophysics

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

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Section A – Nuclear and Thermal Physics

Question	Part	Sub Part	Marking Guidance	Mark	Comments
1	(a)	(i)	1/12 the mass of an (atom) of $^{12}_6\text{C}$ / carbon-12 / C12✓	1	a reference to a nucleus loses the mark
1	(a)	(ii)	separated nucleons have a greater mass ✓ (than when inside a nucleus) because of the (binding) energy added to separate the nucleons or energy is released when a nucleus is formed (owtte) ✓	2	an answer starting with 'its' implies the nucleus marks are independent direction of energy flow or work done must be explicit
1	(b)		nuclei need to be close together (owtte) for the Strong Nuclear Force to be involved or for fusion to take place✓ but the electrostatic/electromagnetic force is repulsive (and tries to prevent this) ✓ (if the temperature is high then) the nuclei have (high) kinetic energy/speed (to overcome the repulsion) ✓	3	e.g. first mark – within the range of the SNF 3 rd mark is for a simple link between temperature and speed/KE
1	(c)	(i)	15 ✓ e^+ ✓ (or β^+ , $^0_1\beta$, ^0_1e) 12 ✓	3	give the middle mark easily for any e or β with a + in any position

1	(c)	(ii)	$\Delta\text{mass} = 4 \times 1.00728 - 4.00150 - (2 \times 9.11 \times 10^{-31} / 1.661 \times 10^{-27})$ or $\Delta\text{mass} = \{4 \times 1.00728 - 4.00150 - 2 \times 0.00055\}(\text{u}) \checkmark$ $\Delta\text{mass} = 0.02652(\text{u}) \checkmark$ $\Delta\text{binding energy} (= 0.02652 \times 931.5) \quad \{\text{allow } 931.3\}$ $\Delta\text{binding energy} = 24.7 \text{ MeV} \checkmark$	3	$(4 \times 1.00728 = 4.02912)$ 1 st mark – correct subtractions in any consistent unit. use of $m_p = 1.67 \times 10^{-27} \text{ kg}$ will gain this mark but will not gain the 2 nd as it will not produce an accurate enough result 2 nd mark – for calculated value 0.02652u $4.405 \times 10^{-29} \text{ kg}$ $3.364 \times 10^{-12} \text{ J}$ 3 rd mark – conversion to MeV conversion mark stands alone award 3 marks for answer provided some working shown – no working gets 2 marks (2sf expected)
2	(a)		insert control rods (further) into the nuclear core/reactor $\checkmark$ which will absorb (more) neutrons (reducing further fission reactions) $\checkmark$	2	a change must be implied for 2 marks marks by use of (further) or (more) allow answers that discuss shut down as well as power reduction If a statement is made that is wrong but not asked for limit the score to 1 mark (e.g. wrong reference to moderator)
2	(b)		fission fragments/daughter products or <u>spent/used</u> fuel/uranium rods (allow) plutonium (produced from U-238) $\checkmark$	1	not uranium on its own
2	(c)	(i)	γ (electromagnetic radiation is emitted) $\checkmark$ as the energy gaps are large (in a nucleus) as the nucleus de-excites down discrete energy levels to allow the nucleus to get to the ground level/state $\checkmark$ mark for reason	2	A reference to α or β loses this first mark 2 nd mark must imply energy levels or states

2	(c)	(ii)	momentum/<u>kinetic energy</u> is transferred (to the moderator atoms) or a neutron slows down/loses <u>kinetic energy</u> (with each collision) ✓ (eventually) reaching speeds associated with thermal random motion or reaches speeds which can cause fission (owtte)✓	2	
3		(i)	(heat supplied by glass = heat gained by cola) (use of $m_g c_g \Delta T_g = m_c c_c \Delta T_c$) $0.250 \times 840 \times (30.0 - T_f) = 0.200 \times 4190 \times (T_f - 3.0)$ ✓ $(210 \times 30 - 210 T_f = 838 T_f - 838 \times 3)$ $T_f = 8.4(1) (^{\circ}\text{C})$ ✓	2	1st mark for RHS or LHS of substituted equation 2nd mark for 8.4°C Alternatives: 8°C is substituted into equation (on either side shown will get mark)✓ resulting in 4620J~4190J ✓ or 8°C substituted into LHS ✓ (produces $\Delta T = 5.5^{\circ}\text{C}$ and hence) = 8.5°C ~ 8°C ✓ 8°C substituted into RHS✓ (produces $\Delta T = 20^{\circ}\text{C}$ and hence) = 10°C ~ 8°C ✓

3		(ii)	(heat gained by ice = heat lost by glass + heat lost by cola) (heat gained by ice = $mc\Delta T + ml$) heat gained by ice = $m \times 4190 \times 3.0 + m \times 3.34 \times 10^5$ ✓ (heat gained by ice = $m \times 346600$) heat lost by glass + heat lost by cola = $0.250 \times 840 \times (8.41 - 3.0) + 0.200 \times 4190 \times (8.41 - 3.0)$ ✓ (= 5670 J) $m (=5670/346600) = 0.016$ (kg) ✓ or (using cola returning to its original temperature) (heat supplied by glass = heat gained by ice) (heat gained by glass = $0.250 \times 840 \times (30.0 - 3.0)$) heat gained by glass = 5670 (J) ✓ (heat used by ice = $mc\Delta T + ml$) heat used by ice = $m(4190 \times 3.0 + 3.34 \times 10^5)$ ✓ (= $m(346600)$) $m (=5670/346600) = 0.016$ (kg) ✓	3	NB correct answer does not necessarily get full marks 3rd mark is only given if the previous 2 marks are awarded (especially look for $m \times 4190 \times 3.0$) the first two marks are given for the formation of the substituted equation not the calculated values if 8°C is used the final answer is 0.015 kg
4	(a)		molecules have negligible volume collisions are elastic the gas cannot be liquified there are no interactions between molecules (except during collisions) the gas obeys the (ideal) gas law / obeys Boyles law etc. at all temperatures/pressures any two lines ✓✓	2	a gas laws may be given as a formula
4	(b)	(i)	$n (= PV / RT) = 1.60 \times 10^6 \times 0.200 / (8.31 \times (273 + 22))$ ✓ = 130 or 131 mol ✓ (130.5 mol)	2	

4	(b)	(ii)	$\text{mass} = 130.5 \times 0.043 = 5.6 \text{ (kg)} \checkmark$ (5.61kg) $\text{density (= mass/volume)} = 5.61 / 0.200 = 28 \checkmark (28.1 \text{ kg m}^{-3})$ $\text{kg m}^{-3} \checkmark$	3	allow ecf from bi a numerical answer without working can gain the first two marks
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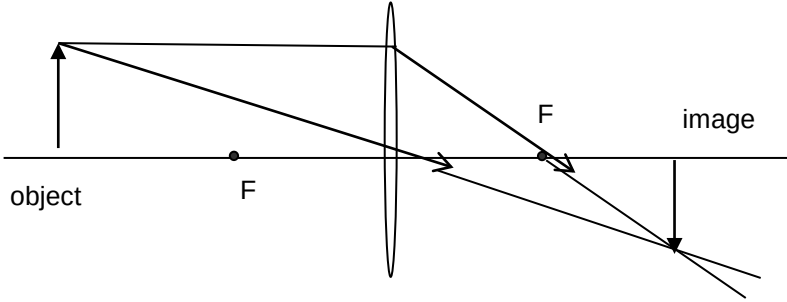
4	(b)	(iii)	$(V_2 = P_1 V_1 T_2 / P_2 T_1)$ $V_2 = 1.6 \times 10^6 \times .200 \times (273 - 50) / 3.6 \times 10^4 \times (273 + 22) \text{ or } 6.7(2)$ $(\text{m}^3) \checkmark$ $\text{mass remaining} = 5.61 \times 0.20 / 6.72 = 0.17 \text{ (kg)} \checkmark (0.167 \text{ kg})$ or $n = (PV / RT = 3.6 \times 10^4 \times 0.200 / (8.31 \times (273 - 50)) = 3.88(5) \text{ (mol)}$ $\checkmark$ $\text{mass remaining} = 3.885 \times 4.3 \times 10^{-2} = 0.17 \text{ (kg)} \checkmark$ 2 sig figs $\checkmark$	3	allow ecf from bii [reminder must see bii] look out for any 2 sf answer gets the mark
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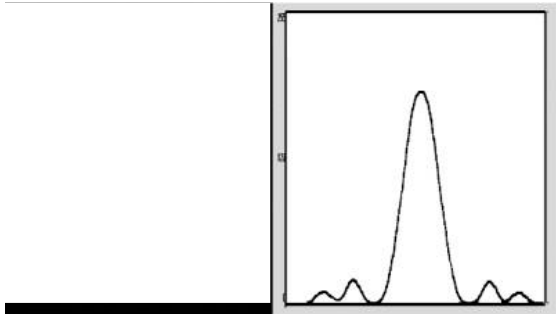
5		The mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC).		
	QWC	Descriptor	Mark range	
	High Level (Good to excellent)	The candidate refers to all the necessary apparatus and records the count-rate at various distances (or thicknesses of absorber). The background is accounted for and a safety precaution is taken. The presence of an α source is deduced from the rapid fall in the count rate at 2 – 5 cm in air. The presence of a γ source is deduced from the existence of a count-rate above background beyond 30 -50 cm in air (or a range in any absorber greater than that of beta particles, e.g. 3 – 6 mm in Al) or from the intensity in air falling as an inverse square of distance or from an exponential fall with the thickness of a material e.g. lead. <i>The information should be well organised using appropriate specialist vocabulary. There should only be one or two spelling or grammatical errors for this mark.</i>	5-6	If more than one source is used or a different experiment than the question set is answered limit the mark to 4

	Intermediate Level (Modest to adequate)	The candidate refers to all the necessary apparatus and records the count-rate at different distances (or thicknesses of absorber). A safety precaution is stated. The presence of an α source is deduced from the rapid fall in the count rate at 2 – 5 cm in air and the γ source is deduced from the existence of a count-rate beyond 30 -50 cm in air (or appropriate range in any absorber, e.g. 3 -6 mm in Al). Some safety aspect is described. One other aspect of the experiment is given such as the background. <i>The grammar and spelling may have a few shortcomings but the ideas must be clear.</i>	3-4	To get an idea of where to place candidate look for 6 items: 1. Background which must be used in some way either for a comparison or subtracted appropriately 2. Recording some data with a named instrument
	Low Level (Poor to limited)	The candidate describes recording some results at different distances (or thicknesses of absorber) and gives some indication of how the presence of α or γ may be deduced from their range. Some attempt is made to cover another aspect of the experiment, which might be safety or background. <i>There may be many grammatical and spelling errors and the information may be poorly organised.</i>	1 - 2	3. Safety reference appropriate to a school setting – not lead lined gown for example 4. Record data with more than one absorber or distances 5. α source determined from results taken 6. γ source determined
		The description expected in a competent answer should include a coherent selection of the following points. apparatus: source, lead screen, ruler, γ ray and α particle detector such as a Geiger Muller tube, rate-meter or counter and stopwatch, named absorber of varying thicknesses may be used. safety: examples include, do not have source out of storage longer than necessary, use long tongs, use a lead screen between source and experimenter. measurements: with no source present switch on the counter for a fixed period measured by the stopwatch and record the number of counts or record the rate-meter reading with the source present measure and record the distance between the source and detector (or thickness of absorber) then switch on the counter for a fixed period measured by the stopwatch and record the number of counts or record the rate-meter reading repeat the readings for different distances (or thicknesses of absorber).		from results taken this is a harder mark to achieve it may involve establishing an inverse square fall in intensity in air or an exponential fall using thicknesses of lead if a continuous distribution is not used an absorber or distance in air that would just eliminate β (30-50cm air / 3-6mm Al) must be used with and without the source being present or compared to background

		use of measurements: for each count find the rate by dividing by the time if a rate-meter was not used subtract the background count-rate from each measured count-rate to obtain the corrected count-rate longer recording times may be used at longer distances (or thickness of absorber). plot a graph of (corrected) count-rate against distance (or thickness of absorber) or refer to tabulated values plot a graph of (corrected) count-rate against reciprocal of distance squared or equivalent linear graph to show inverse square relationship in air analysis: the presence of an α source is shown by a rapid fall in the (corrected) count-rate when the source detector distance is between 2 – 5 cm in air the presence of a γ source is shown if the <u>corrected</u> count-rate is still present when the source detector distance is greater than 30 cm in air (or at a range beyond that of beta particles in any other absorber, e.g. 3 mm in Al) the presence of a γ source is best shown by the graph of (corrected) count-rate against reciprocal of distance squared being a straight line through the origin		
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Section B – Astrophysics

Question	Part	Sub Part	Marking Guidance	Mark	Comments
1	a		 One construction ray correct ✓ Other construction ray to form diminished image ✓ (The parallel construction ray must pass through a labelled F) Object, image labelled correctly. ✓	3	Arrows are not essential Condone only one focus if it is the one used for the construction ray. Construction ray must have focus labelled to get the mark. Lose the second mark if the image is same size or magnified Image line is needed for second mark.
1	b		$u = 128 \text{ cm}$ $v = 200 - 128 = 72 \text{ cm}$ ✓ Use of $1/f = 1/u + 1/v$ To give $1/f = 1/128 + 1/72$ $f = 46 \text{ cm}$ ✓	2	Allow c.e. for incorrect v Condone u and v the wrong way round.
1	c		Objective. As $M = f_o/f_e$, for magnification $f_o > f_e$ ✓ As telescope length = $f_o + f_e$, lens must be objective (so that telescope not too long.) ✓	2	No credit for unsupported answer.

2	a	i	central maximum at least twice the height of adjacent maxima ✓ Subsequent narrower maxima. ✓ 	2	Allow graph to be above angle axis Any further maxima should not get bigger.
2	a	ii	Two sources will be (just) resolved if the central maximum of the diffraction pattern of one coincides ✓ with the first minimum of the other. ✓	2	Central max and first min may be labelled on diagram in 2ai If they use the term 1st maximum it must be clear that it is the central maximum Second mark is for correct part of the second diffraction pattern. Clearly labelled diagram can get both marks.
2	b		Use of $10^8)^2$ ✓ $R_s = 2GM/c^2$ $R_s = 2 \times 6.67 \times 10^{-11} \times 4.1 \times 10^6 \times 2 \times 10^{30} / (3 \times 10^8)^2$ $= 1.2 \times 10^{10} \text{ m}$ ✓ 2sf ✓	3	Allow ce for one from: missing out million; missing out mass of Sun; square in equation, but no square of speed of light in calculation Sf mark stands alone but must be a number (not just stated 2 sf)

2	c	i	use of to give $\theta = \lambda/D$ $\theta = (3 \times 10^8 / 230 \times 10^9) \checkmark / 5000 \times 10^3$ $= 2.6 \times 10^{-10} \text{ (rad)} \checkmark$	2	The first mark is for calculating the wavelength The second mark is for the use of the equation to give the final answer Allow c.e. for an a.e. in the first mark. If frequency used treat as p.e. – no marks
2	c	ii	use of to give $s = r\theta$ $\theta = 5 \times 1.2 \times 10^{10} / (25\,000 \times 9.46 \times 10^{15}) \checkmark$ $= 2.5 \times 10^{-10} \text{ (rad)} \checkmark$ which is (approximately) the answer to 2ci	2	First mark is for the angle subtended (5.12×10^{-11}) Second mark is for showing that this is 5 x answer to c(i). Alternatives: Calculate size of object that could just be resolved at this distance, and showing that this is 5 x radius of black hole.
3			The marking scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC). There are no discrete marks for the assessment of written communication but the quality of written communication will be one of the criteria used to assign the answer to one of three levels. The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.	6	There are three areas: Structure: silicon chip into pixels Function: photon incident, electron excited, electron trapped in potential well, one electron per photon, no of electrons (and therefore charge) proportional to number of incident photons, after sufficient exposure charge on each pixel measured and image produced Advantage: most will say the QE>70%
			High Level (Good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.		A 6 mark answer need not be "perfect" but should be substantially complete, correct and free from major errors. One of the above points may be missing. Eg charge integration

			The candidate provides a comprehensive and logical description of the structure of the CCD. The answer includes a clear description of how the light causes a release of charge and why the charge is stored. The answer also includes an explanation of what is meant by quantum efficiency and a correct value for the q.e. of a CCD. Confusion with the photoelectric effect would reduce a 6 mark answer to 5.		5 marks may have 2 missing eg silicon chip and charge integration
			Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate provides a comprehensive and logical description of the CCD. The answer demonstrates some understanding of how the light is used to generate charge. The answer also includes some reference the efficiency of the CCD or other advantage		4 probably has more than 2 missing or no correct advantage
			Low Level (Poor to limited): 1 or 2 marks. The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate demonstrates an understanding that an image is formed on the CCD and that this image is transferred to a computer.		
			Zero: Incorrect, inappropriate or no response.		
			Points that can be used to support the explanation: • The CCD is a silicon chip • The chip is divided into picture elements • Each picture element is associated with a potential well in the silicon • Incident photons are focused on the CCD • The photons cause the release of electrons within the semiconductor • The number of electrons liberated is proportional to the intensity of the light. • Electrons are trapped in the potential wells • An electron pattern is built up which is identical to the image formed on the CCD. • When exposure is complete the charge is processed to form an image.		

			Advantages: High quantum efficiency > 70% Light integration – using long exposure times to capture faint images. Device can be directly linked to computer for capture and analysis.		
4	a	i	Similarity both would appear the same <u>brightness</u> As the apparent magnitudes are the same ✓ Difference Kocab would appear orange/red, Polaris yellow/white Due to their spectral classes/ different temperatures ✓	2	Description and explanation needed for mark. Any references to same size gets zero for 1 st mark. Allow different colours + ref to spectral class for second mark If colour named, should be correct.
4	a	ii	Polaris is further from Earth: Both stars same size and Polaris is hotter ✓ As $P = \sigma AT^4$ Same A, would mean that Polaris has greater power output. ✓ Polaris must be further from Earth to appear same brightness as Kocab. ✓	3	Alternative: Polaris hotter and same size Hence, Polaris has brighter absolute magnitude/ is intrinsically brighter Same apparent brightness, therefore Polaris is further away.
4	b	i	$v = Hd$ $v = 0.025 \times 3 \times 10^5 = 7.5 \times 10^3 \text{ km s}^{-1}$ ✓ $d = 340 \times 10^6 \text{ l yr} = 340 / 3.26 \text{ Mpc} = 104 \text{ Mpc}$ ✓ $H = 7.5 \times 10^3 / 104 = 72 \text{ kms}^{-1} \text{ Mpc}^{-1}$ ✓	3	1 st mark is for calculating v 2 nd mark is for working out d in Mpc 3 rd mark is for calculating H in the correct unit.
4	b	ii	Age of Universe = $1/H$ $= 0.014 \times 10^6 \times 3.26 \times 9.5 \times 10^{15} / 1000$ $= 4.3 \times 10^{17} \text{ seconds}$ (= 13.6 billion years) Unit consistent with calculation.	3	1 st mark is for the equation 2 nd is for the answer with working 3 rd is for a time unit consistent with their answer/working

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 2012

Physics A

PHYA5/2A

Unit 5A Astrophysics Section B

Monday 18 June 2012 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.



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WMP/Jun12/PHYA5/2A

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PHYA5/2A

Section B

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

- 1 (a) (i)** Draw a ray diagram to show how a converging lens forms a magnified real image of a real object. Label a principal focus on your diagram.

(2 marks)

- 1 (a) (ii)** Draw a ray diagram to show how a converging lens forms a magnified virtual image of a real object. Label a principal focus on your diagram.

(2 marks)



- 1 (b) (i)** A converging lens of focal length 145 mm is used to produce an image of an object placed 112 mm from the lens. Calculate the image distance. Give your answer to an appropriate number of significant figures.

answer = ... mm
(3 marks)

- 1 (b) (ii)** State **three** properties of the image.

.....
.....
.....
(1 mark)

8

Turn over for the next question

Turn over ►



2 TRAPPIST is a robotic telescope designed to detect exoplanets, which are planets outside our solar system.

2 (a) The charge coupled device (CCD) attached to TRAPPIST has a *quantum efficiency* of 96% for light of wavelength 750 nm.

Explain what is meant by the quantum efficiency of a CCD.

.....

.....

(1 mark)

2 (b) (i) The optical arrangement of the telescope includes an objective mirror of diameter 0.60 m.

Calculate the minimum angular separation of two objects which can be resolved by the telescope for light of wavelength 750 nm.

answer = ... rad
(1 mark)



- 2 (b) (ii)** One of the nearest exoplanets orbits the star Epsilon Eridani, which is 10.5 light years from Earth. The exoplanet has an elliptical orbit, whose orbital radius varies from 1 AU to 5 AU.
Calculate the maximum angular separation of the star and the planet when viewed from a distance of 10.5 light years.

answer = ... rad
(3 marks)

- 2 (b) (iii)** TRAPPIST detects the presence of exoplanets by measuring the reduction in light intensity that occurs as the planet passes in front of the star.
Explain why it is unlikely that the telescope could be used to observe such planets directly.

.....
.....
.....
(1 mark)

Question 2 continues on the next page

Turn over ►



The quality of your written communication will be assessed in your answer.

This image shows a single page of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

12



- 3** Bellatrix and Betelgeuse are stars in the constellation of Orion. Some of their properties are summarised below.

	Bellatrix	Betelgeuse
absolute magnitude	−6.0	−2.7
apparent magnitude	0.4	1.6
black-body temperature / K	22 000	2 400

- 3 (a) (i)** Explain what is meant by absolute magnitude.

.....

.....

.....

(1 mark)

- 3 (a) (ii)** Which of the two stars is closer to the Earth? Explain your answer.

.....

.....

.....

(1 mark)

- 3 (b) (i)** Calculate the wavelength of the peak intensity in the black-body radiation curve of Bellatrix.

answer = ... m

(2 marks)

Turn over ►



- 3 (b) (ii)** Sketch the black-body radiation curve for Bellatrix. Label the wavelength axis with a suitable scale.



(3 marks)

- 3 (c)** Detailed analysis of the light from both stars reveals the presence of prominent absorption lines in the spectra.

- 3 (c) (i)** To which spectral class does Bellatrix belong?

.....
(1 mark)

- 3 (c) (ii)** Prominent features in the Bellatrix spectrum are the Balmer absorption lines due to hydrogen. State the other element responsible for the prominent absorption lines in the spectrum of Bellatrix.

.....
(1 mark)

- 3 (c) (iii)** Why does the spectrum of Betelgeuse not contain prominent Hydrogen Balmer absorption lines?

.....
.....
.....
(1 mark)



4 Cygnus A may be the nearest quasar yet discovered.

4 (a) Cygnus A has a redshift, z , of 0.057.
Calculate the distance to Cygnus A. State an appropriate unit.

answer = ... unit = ...
(4 marks)

4 (b) The first quasars were discovered in the 1950s. What property of quasars led to their discovery?

.....
.....
(1 mark)

5

END OF QUESTIONS



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General Certificate of Education (A-level)
June 2012

Physics A

PHYA5/2A

(Specification 2450)

Unit 5/2A: Astrophysics

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this Mark Scheme are available from: aqa.org.uk

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Instructions to Examiners

- 1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors, specific instructions are given in the marking scheme.
- 2 Do not deduct marks for poor written communication. Refer the scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (eg relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (ie in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

QWC	descriptor	mark range
Good - Excellent	<i>see specific mark scheme</i>	5-6
Modest - Adequate	<i>see specific mark scheme</i>	3-4
Poor - Limited	<i>see specific mark scheme</i>	1-2
The description and/or explanation expected in a good answer should include a coherent account of the following points: <i>see specific mark scheme</i>		

Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

- 3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks.
- 4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.
- 5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.
- 6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.
- 7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

GCE Physics, Specification A, PHYA5/1, Nuclear and Thermal Physics

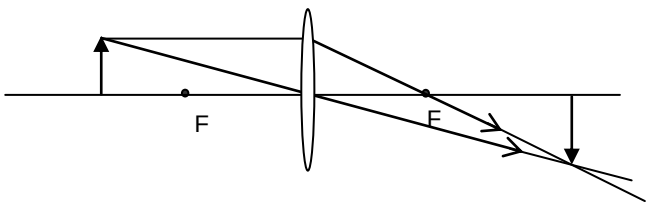
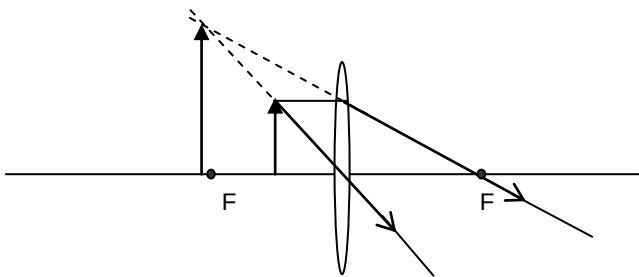
1	a		$\Delta T = \left(\frac{\Delta Q}{mc}\right) = \frac{8.5 \times 10^3}{4200 \times 0.12} \checkmark$ 17 K $\checkmark$	2
1	b		$\left(\frac{\Delta T}{\Delta t} = \frac{\frac{\Delta Q}{\Delta t}}{mc}\right) = \frac{100 - 26}{\Delta t} = \frac{8.5 \times 10^3}{0.41 \times 4200} \checkmark$ $t = 15 \text{ s} \checkmark$	2
2	a		$({}^{206}_{76}\text{X} \rightarrow {}^{206}_{82}\text{Pb} + \beta + {}^0_{-1}\beta + \beta \times \bar{\nu}_e)$ $\beta = 6 \checkmark$	1
2	b	i	the energy required to split up the nucleus $\checkmark$ into its individual neutrons and protons/nucleons $\checkmark$ (or the energy released to form/hold the nucleus $\checkmark$ from its individual neutrons and protons/nucleons $\checkmark$)	2
2	b	ii	$7.88 \times 206 = 1620 \text{ MeV} \checkmark$ (allow 1600-1640 MeV)	1
2	c	i	U, a graph starting at 3×10^{22} showing exponential fall passing through 0.75×10^{22} near 9×10^9 years $\checkmark$ Pb, inverted graph of the above so that the graphs cross at 1.5×10^{22} near 4.5×10^9 years $\checkmark$	2
2	c	ii	(u represents the number of uranium atoms then) $\frac{u}{3 \times 10^{22} - u} = 2$ $u = 6 \times 10^{22} - 2u \checkmark$ $u = 2 \times 10^{22}$ atoms	1
2	c	iii	(use of $N = N_0 e^{-\lambda t}$) $2 \times 10^{22} = 3 \times 10^{22} \times e^{-\lambda t} \checkmark$ $t = \ln 1.5 / \lambda$ (use of $\lambda = \ln 2 / t_{1/2}$) $\lambda = \ln 2 / 4.5 \times 10^9 = 1.54 \times 10^{-10} \checkmark$ $t = 2.6 \times 10^9 \text{ years} \checkmark$ (or $2.7 \times 10^9 \text{ years}$)	3
3	a		any 2 from: the sun, cosmic rays, radon (in atmosphere), nuclear fallout (from previous weapon testing), any radioactive leak (may be given by name of incident) nuclear waste, carbon-14 $\checkmark$	1

3	b	i	(ratio of area of detector to surface area of sphere) ratio = $\frac{0.0015}{4\pi(0.18)^2}$ ✓ 0.0037 ✓ (0.00368)	2
3	b	ii	activity = $0.62/(0.00368 \times 1/400)$ give first mark if either factor is used. 67000 ✓ Bq accept s^{-1} or decay/photons/disintegrations s^{-1} but not counts s^{-1} ✓ (67400 Bq)	3
3	c		(use of the inverse square law) $\frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2$ or calculating $k = 0.020$ from $I = k/x^2$ ✓ $I_2 = 0.62 \times \left(\frac{0.18}{0.28}\right)^2$ ✓ 0.26 counts s^{-1} ✓ (allow 0.24-0.26)	3
4	a	i	$n = PV/RT = 3.2 \times 10^5 \times 1.9 \times 10^{-3}/8.31 \times 285$ $n = 0.26$ mol ✓ (0.257 mol)	1
4	a	ii	$P_2 = \frac{T_2}{T_1} \times P_1 = \frac{295}{285} \times 3.20 \times 10^5$ ✓ 3.31×10^5 Pa ✓ (allow 3.30 - 3.35×10^5 Pa) 3 sig figs ✓ sig fig mark stands alone even with incorrect answer	3
4	b		similar - (rapid) random motion - range of speeds different - mean kinetic energy - root mean square speed - frequency of collisions	2
5	a		graph starting (steeply) near/at the origin and decreasing in gradient ✓	1
5	b	i	(use of density = mass/volume) $\frac{197 \times 1.67 \times 10^{-27}}{\frac{4}{3}\pi(6.87 \times 10^{-15})^3}$ ✓✓ mark for top line and mark for bottom line (allow use of 1.66×10^{-27}) Lose mass line mark if reference is made to mass of electrons $= 2.4(2) \times 10^{17}$ kg m^{-3}	2

5	b	ii	$R_{A1} = R_{Au} \left(\frac{A_{A1}}{A_{Au}} \right)^{\frac{1}{3}} = 6.87 \times 10^{-15} \left(\frac{27}{197} \right)^{\frac{1}{3}} \checkmark$ $= 3.54 \times 10^{-15} \text{ m } \checkmark$ or $r_0 = \frac{R}{A^{\frac{1}{3}}} = \frac{6.87 \times 10^{-15}}{197^{\frac{1}{3}}} = 1.18 \times 10^{-15} \text{ m } \checkmark$ $R = 1.18 \times 10^{-15} \times 27^{\frac{1}{3}} = 3.54 \times 10^{-15} \text{ m } \checkmark$ or $\text{volume} = \text{mass/density} = \frac{27 \times 1.67 \times 10^{-27}}{2.42 \times 10^{17}} = \frac{4}{3} \pi \times R^3 \checkmark$ $= 3.54 \times 10^{-15} \text{ m } \checkmark$	2
5	c		The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. High Level (Good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. <i>The candidate makes 5 to 6 points concerning the principles of the method, the limitations to the accuracy and the advantages and disadvantages of a particular method</i> Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. <i>The candidate makes 3 to 4 points concerning the principles of the method, the limitations to the accuracy and the advantages and disadvantages of a particular method</i> Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. <i>The candidate makes 1 to 2 points concerning the principles of the method, the limitations to the accuracy and the advantages and disadvantages of a particular method</i>	max 6

			The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences. principles • α scattering involves coulomb or electrostatic repulsion • electron diffraction treats the electron as a wave having a de Broglie wavelength • some reference to an equation, for example $\lambda = h/mv$; $eV = mv^2/2$; $Qq/4\pi\epsilon_0 r = E_\alpha$; $\sin\theta = 0.61\lambda/R$ • reference to first minimum for electron diffraction accuracy • α's only measure the least distance of approach, not the radius • α's have a finite size which must be taken into account • electrons need to have high speed/kinetic energy • to have a small wavelength or wavelength comparable to nuclear diameter, the wavelength determines the resolution • the wavelength needs to be of the same order as the nuclear diameter for significant diffraction • requirement to have a small collision region in order to measure the scattering angle accurately • importance in obtaining monoenergetic beams • cannot detect alpha particles with exactly 180° scattering • need for a thin sample to prevent multiple scattering advantages and disadvantages • α-particle measurements are disturbed by the nuclear recoil • Mark for α-particle measurements are disturbed by the SNF when coming close to the nucleus or electrons are not subject to the strong nuclear force. • A second mark can be given for reference to SNF if they add electrons are leptons or alpha particles are hadrons. • α's are scattered only by the protons and not all the nucleons that make up the nucleus • visibility – the first minimum of the electron diffraction is often difficult to determine as it superposes on other scattering events	
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GCE Physics, Specification A, PHYA5/2A, Astrophysics

1	a	i	 Two correct rays, one through marked focal point. ✓ to form a magnified real image ✓	2
1	a	ii	 Two correct rays ✓ to form virtual image ✓	2
1	b	i	use of $1/f = 1/u + 1/v$ to give $1/145 = 1/112 + 1/v$ ✓ and $v = -492 \text{ mm}$ ✓ 3 sf ✓	3
1	b	ii	virtual, magnified, upright ✓	1
2	a		the percentage of photons hitting the CCD which are detected and/or produce a signal ✓	1
2	b	i	use of $\theta = \lambda/D$ to give $\theta = 750 \times 10^{-9}/0.60$ $= 1.25 \times 10^{-6} \text{ (rad)}$ ✓	1
2	b	ii	use of $s = r\theta$ to give $\theta = 5 \times 1.5 \times 10^{11} \text{ ✓} / 10.5 \times 9.46 \times 10^{15} \text{ ✓}$ $= 7.55 \times 10^{-6} \text{ ✓ (rad)}$	3

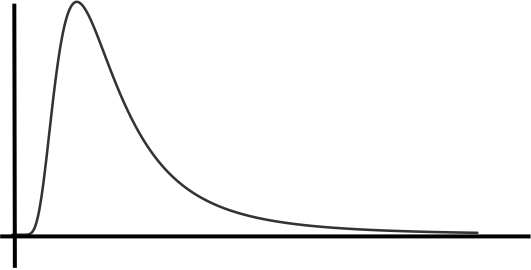
2	b	iii	either answer 2bi is theoretical limit – and in reality resolving power will be much poorer than this (due to atmosphere etc) or planets will be far too dim to see (next to star) ✓	1
2	c		The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. High Level (Good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. <i>The candidate provides a comprehensive and logical explanation which considers the detection of three named parts of the electromagnetic spectrum.</i> <i>The candidate describes how the optimum siting of a telescope is determined by the effect the atmosphere and, for full marks, other factors, such as light pollution, have on three named parts of the electromagnetic spectrum.</i> <i>They also demonstrate an understanding of how resolving power, and for full marks, the collecting power, of a telescope is affected by the size of the aperture, and relate the resolving power to the wavelengths of the three different parts of the electromagnetic spectrum.</i> Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. <i>The candidate provides a comprehensive and logical explanation which names two or three parts of the electromagnetic spectrum and discusses both siting and size for at least two for 4 marks, or for one of them for 3 marks.</i> <i>The candidate may recognise that some telescopes need to be in orbit due to the absorption of some parts of the em spectrum by the atmosphere. They may also discuss the positioning of telescopes eg they should be high up to reduce absorption of IR. Their answer may refer to only resolving or collecting power when discussing the size of telescopes and there may be little attempt or, for three marks, no attempt to relate resolving power to wavelength.</i> Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.	max 6

			<i>The candidate recognises some telescopes are in orbit, and for two marks, they may describe a part of the electromagnetic spectrum being detected.</i> <i>They may confuse which parts of the electromagnetic spectrum are absorbed by the atmosphere and which pass through.</i> <i>They may make, for two marks a vague reference to the size of telescopes, and for one mark they may make no reference at all.</i>	
			Points that can be used to support the explanation: Siting • Apart from visible and some parts of the radio wave section, all the other parts of the em spectrum are significantly absorbed by the atmosphere. • To reduce the effects of absorption, IR telescopes are often placed in dry areas and/or very high up. • UV is significantly absorbed by the ozone layer, so UV telescopes are generally put into orbit. • X-ray telescopes are also put into orbit to avoid atmospheric absorption. • To avoid atmospheric distortion, visible telescopes are often placed high up. • To avoid interference from terrestrial sources, radio telescopes may be situated away from centres of population. • To avoid light pollution, visible telescopes are often placed a long way from centres of population. Size • Telescopes are often built as large as possible in order to increase the collecting power, which is proportional to the diameter². • The diameter of the objective of telescopes is also often as large as possible in order to improve the resolving power, as minimum angle resolved is proportional to 1/diameter.	

3	a	i	the brightness of a star as it would appear from a distance of 10 pc ✓	1
---	---	---	--	---

3	a	ii	Betelgeuse Bellatrix is actually a lot brighter than Betelgeuse (the absolute magnitude is a lot more negative), but only appears to be a bit brighter (the apparent magnitude is only a little smaller) so Betelgeuse must be closer ✓	1
---	---	----	---	---

3	b	i	use $\lambda_{\max} T = 0.0029$ of gives $\lambda_{\max} = 0.0029/22\ 000$ ✓ $= 1.32 \times 10^{-7}$ (m) ✓	2
---	---	---	---	---

3	b	ii	intensity  steeper LHS than RHS ✓ intensity goes towards zero as the wavelength goes to end of axis ✓ wavelength scale with peak near 130 nm ✓	3
3	c	i	B ✓	1
3	c	ii	helium ✓	1
3	c	iii	temperature too low (for atmosphere of Betelgeuse to have hydrogen in n=2 state) ✓	1
4		a	use of $z = v/c$ to give $v = zc = 0.057 \times 3 \times 10^8 \checkmark$ $= 1.71 \times 10^7 \text{ ms}^{-1} = 1.71 \times 10^4 \text{ kms}^{-1}$ use of $v = Hd$ to give $d = v/H = 1.71 \times 10^4 / 65 \checkmark$ $= 263 \checkmark \text{ Mpc} \checkmark$	4
4		b	(Strong) radio sources ✓	1

UMS conversion calculator www.aqa.org.uk/umsconversion

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 2011

Physics A

PHYA5/2A

Unit 5A Astrophysics Section B

Monday 27 June 2011 9.00 am to 10.45 am

For this paper you must have:

- a calculator
- a ruler
- a Data and Formulae Booklet.

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.

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.



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WMP/Jun11/PHYA5/2A

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PHYA5/2A

Section B

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

- 1 (a)** Draw the ray diagram for a Cassegrain telescope. Your diagram should show the paths of two rays, initially parallel to the principal axis, as far as the eyepiece.

(2 marks)

- 1 (b)** A telescope design very similar to the Cassegrain was first proposed by James Gregory in 1663. His telescope design was also the first to include a parabolic primary reflector.
- 1 (b) (i)** The use of a parabolic reflector overcomes the problem of *spherical aberration*. Draw a ray diagram to show how spherical aberration is caused by a concave spherical mirror.

(1 mark)



- 1 (b) (ii)** The first telescope constructed to this design had a primary mirror of diameter 0.15 m. Calculate the minimum angular separation which could be resolved by this telescope when observing point sources of light of wavelength 630 nm. State an appropriate unit.

answer = ...

(2 marks)

- 1 (b) (iii)** The astronomer Edmund Halley claimed to have used this telescope to observe the Cassini division, a dark band in the rings of Saturn. Calculate the angle subtended by the width of this band at the Earth, and comment on whether Halley's claim is likely to be valid.

width of Cassini division = 4.8×10^3 km

distance from Earth to Saturn = 1.4×10^9 km

answer = ...

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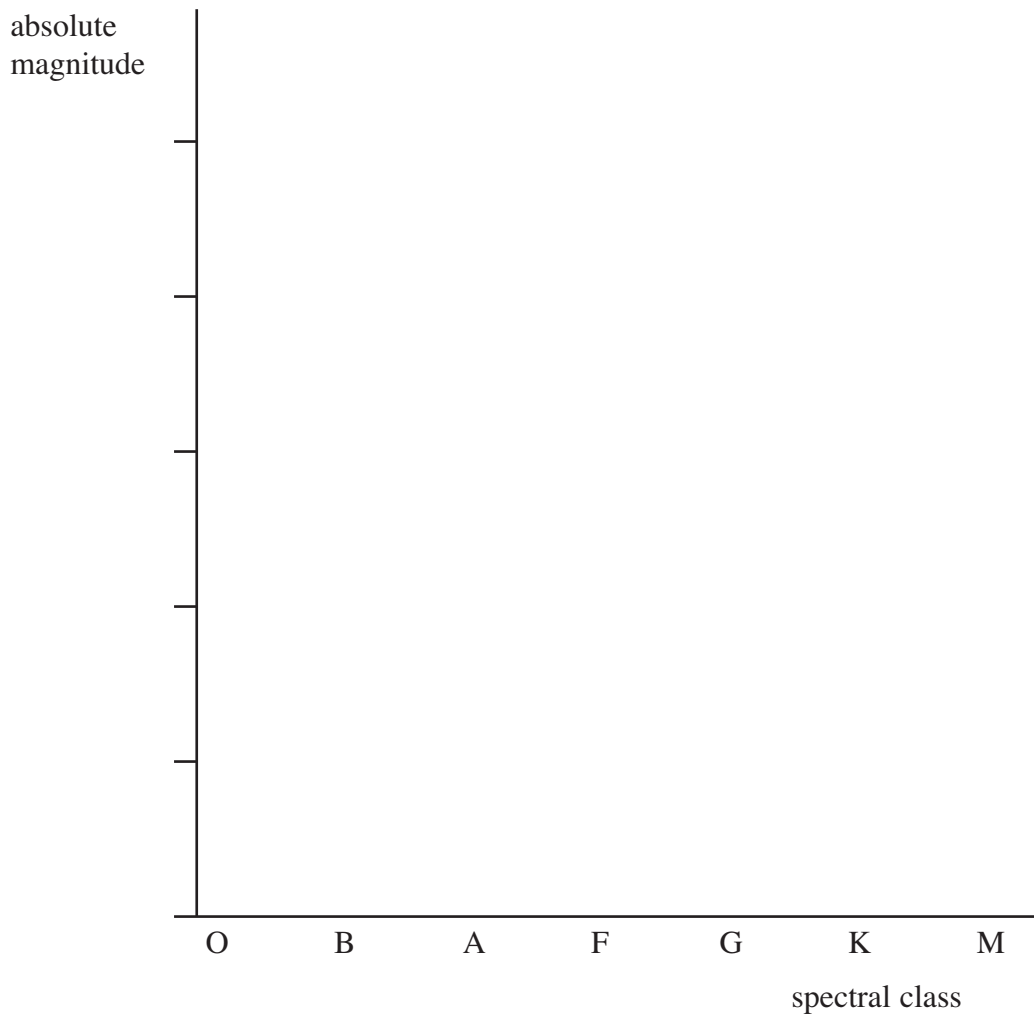
(2 marks)

7

Turn over ►



- 2 (a)** On the axes below draw the Hertzsprung-Russell (H-R) diagram, labelling the main sequence stars, giant stars and white dwarf stars. Complete the vertical axis by labelling a suitable absolute magnitude scale.



(3 marks)



2 (b) Deneb is the brightest star in the constellation Cygnus.

2 (b) (i) The black-body radiation curve for Deneb shows a peak at a wavelength of 3.4×10^{-7} m. Calculate the black-body temperature of Deneb. Give your answer to an appropriate number of significant figures.

answer = ...K
(3 marks)

2 (b) (ii) The power output of Deneb is 70000 times greater than the Sun. Calculate the radius of Deneb.
surface temperature of the Sun = 5700 K

answer = ...m
(3 marks)

Turn over ►



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

[illegible]

15



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ANSWER IN THE SPACES PROVIDED**

Turn over ►



3 The Antennae Galaxies are a pair of colliding galaxies in the constellation Corvus.

3 (a) Measurements of the *red shift* of radio signals from the galaxies suggest they are approximately 25 Mpc from the Earth.

3 (a) (i) Explain what is meant by red shift.

.....

.....

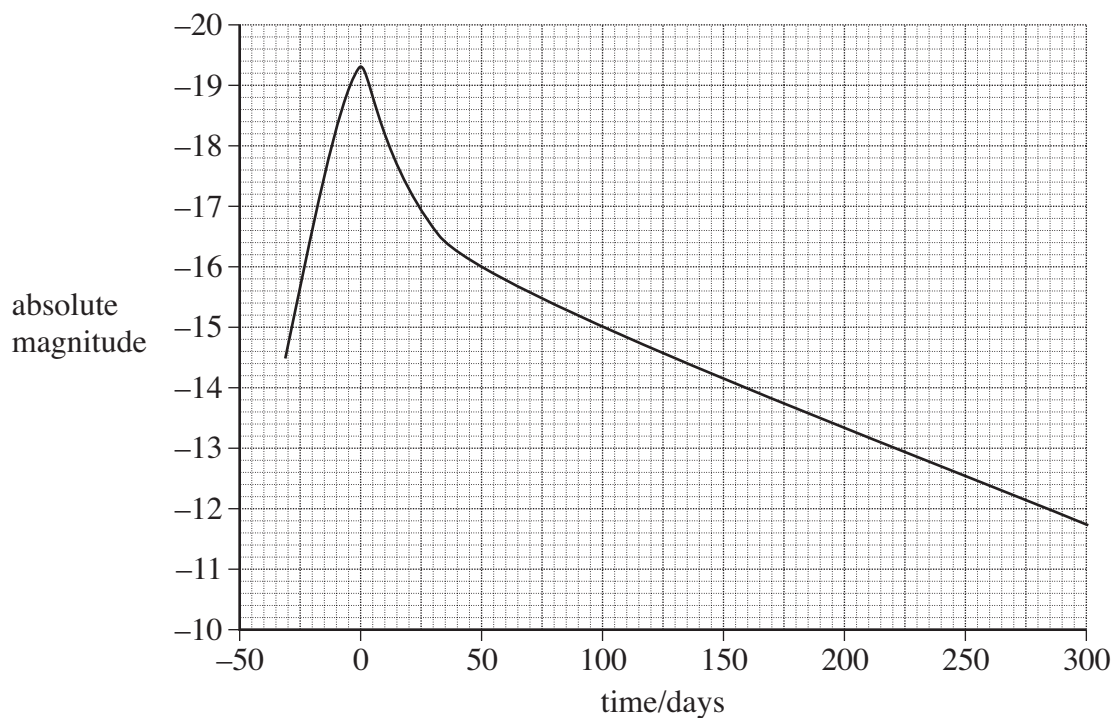
(1 mark)

3 (a) (ii) Calculate the recessive velocity of the Antennae Galaxies.

answer = ... km s⁻¹
(2 marks)

3 (b) SN 2008sr was a type 1a supernova detected in the Antennae Galaxies. **Figure 1** is the light curve of a type 1a supernova.

Figure 1



- 3 (b) (i)** With reference to **Figure 1**, explain why type 1a supernovae can be used as standard candles to determine distances.

.....

.....

.....

.....

.....

(2 marks)

- 3 (b) (ii)** The peak value for the apparent magnitude of this supernova was 12.9. Using this measurement and information from **Figure 1**, calculate the distance to the Antennae Galaxies in Mpc.

answer = ...Mpc
(2 marks)

- 3 (c)** Why is it important for astronomers to have several independent methods of determining the distance to galaxies?

.....

.....

(1 mark)

8

Turn over ►



- 4** Centaurus A is the nearest example of an active galactic nucleus. Many astronomers believe a supermassive black hole at the centre of such a galaxy produces a quasar as it consumes the material of its nearby stars.

- 4 (a)** Explain what is meant by the event horizon of a black hole.

.....

.....

.....

(1 mark)

- 4 (b) (i)** The mass of the black hole is 60 million times the mass of the Sun. Calculate the radius of its event horizon.

answer = ...m
(2 marks)

- 4 (b) (ii)** Calculate the average density of the matter within its event horizon.

answer = ...kg m⁻³
(2 marks)

END OF QUESTIONS



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General Certificate of Education (A-level)
June 2011

Physics A

PHYA5/2A

(Specification 2450)

Unit 5/2A: Astrophysics

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

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Instructions to Examiners

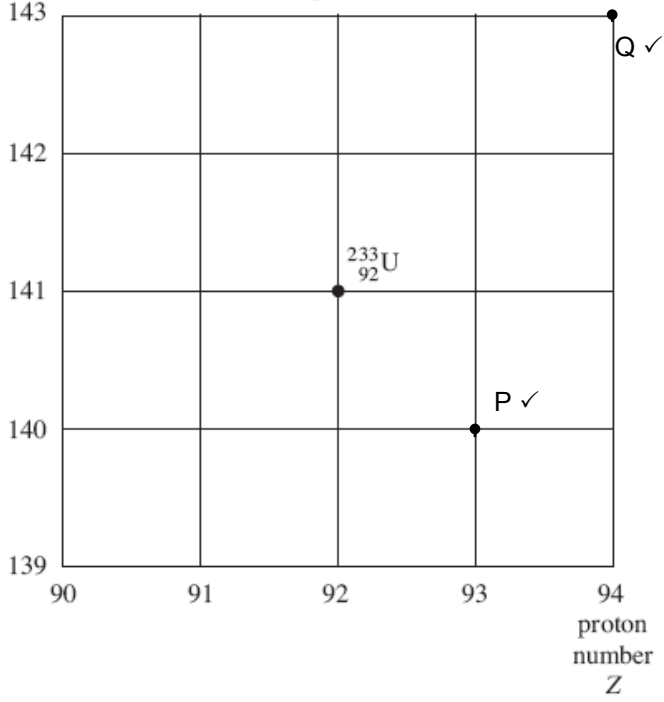
- 1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors, specific instructions are given in the marking scheme.
- 2 Do not deduct marks for poor written communication. Refer the scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (eg relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (ie in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

QWC	descriptor	mark range
Good - Excellent	<i>see specific mark scheme</i>	5-6
Modest - Adequate	<i>see specific mark scheme</i>	3-4
Poor - Limited	<i>see specific mark scheme</i>	1-2
The description and/or explanation expected in a good answer should include a coherent account of the following points: <i>see specific mark scheme</i>		

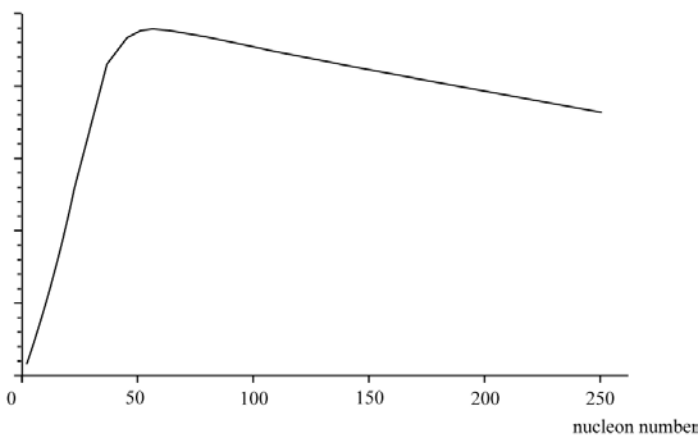
Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

- 3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks.
- 4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.
- 5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.
- 6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.
- 7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

GCE Physics, Specification A, PHYA5/1, Nuclear and Thermal Physics

Question 1		
a	${}_{91}^{233}\text{Pa}$ ✓ anti (electron) neutrino ✓	2
b		2
c i	$x = 4$ ✓	1
c ii	mass defect = $[(232.98915 + 1.00867) - (90.90368 + 138.87810 + 4 \times 1.00867)] \text{ u}$ ✓ $= 0.18136 \text{ u}$ ✓ energy released $(= 0.18136 \times 931) = 169 \text{ (MeV)}$ ✓	3
Total		8

Question 2		
a	${}_{13}^{27}\text{Al} + \alpha \rightarrow {}_{15}^{30}\text{P} + {}_0^{(1)}\text{n}$ ✓	1
b	kinetic energy lost by the α particle approaching the nucleus is equal to the potential energy gain ✓ $2.18 \times 10^{-12} = \frac{1}{4\pi \times 8.85 \times 10^{-12}} \times \frac{13 \times 1.6 \times 10^{-19} \times 2 \times 1.6 \times 10^{-19}}{r}$ ✓ $r = 2.75 \times 10^{-15} \text{ (m)}$ ✓	3
Total		4

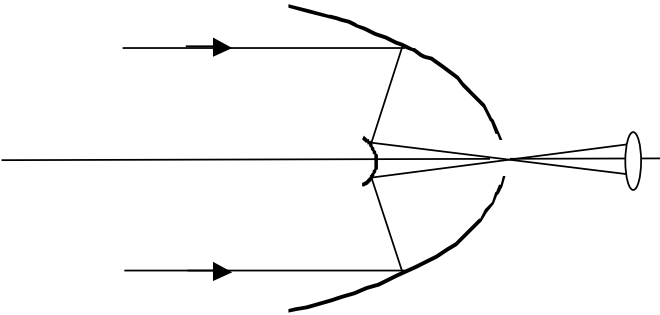
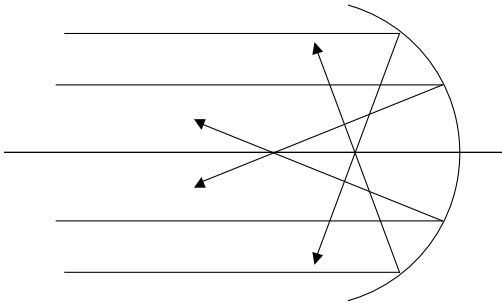
Question 3		
a	binding energy per nucleon  peak 8.7 (accept 8.0 – 9.2) ✓ in MeV ✓ (or peak 1.4×10^{-12} accept $1.3 - 1.5 \times 10^{-12}$ ✓ in J ✓) at nucleon number 50 – 60 ✓ accept 50 – 75 sharp rise from origin and moderate fall not below 2/3 of peak height ✓	4
b	energy is released/made available when binding energy per nucleon is increased ✓ in fission a (large) nucleus splits and in fusion (small) nuclei join ✓ the most stable nuclei are at a peak ✓ fusion occurs to the left of peak and fission to the right ✓	max 3
Total		7

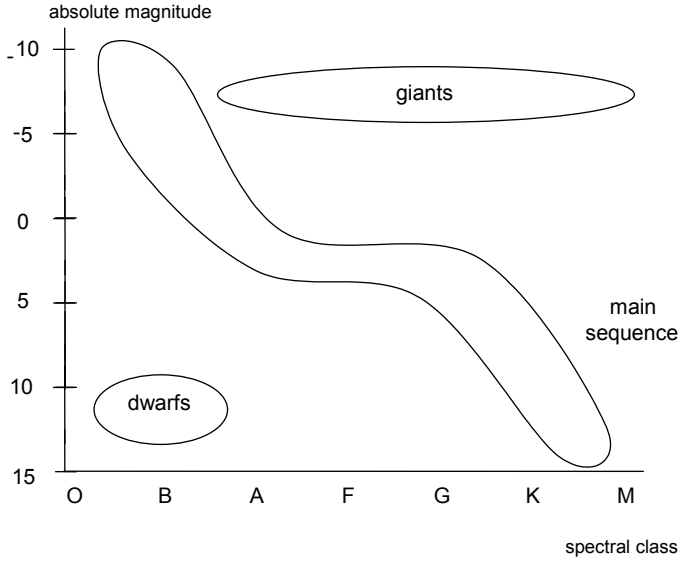
Question 4		
a	(use of $\Delta Q = mc\Delta T$) $30 \times 98 = 0.100 \times c \times 14$ ✓ $c = 2100 \text{ (J kg}^{-1} \text{ K}^{-1})$ ✓	2
b	(use of $\Delta Q = ml + mc\Delta T$) $500 \times 98 = 0.100 \times 3.3 \times 10^5$ ✓ + $0.100 \times 4200 \times \Delta T$ ✓ $(\Delta T = 38^\circ\text{C})$ $T = 38^\circ\text{C}$ ✓	3
c	the temperature would be higher ✓ as the ice/water spends more time below 25°C or heat travels in the direction from hot to cold or ice/water first gains heat then loses heat any one line ✓	2
Total		7

Question 5		
a	graph passes through given point $2.2 \times 10^{-3} \text{ m}^3$ at 0°C straight line with positive gradient ✓ (straight) line to aim or pass through -273°C at zero volume ✓	2
b	(use of $n = P V / R T$) $1.00 \times 10^5 \times 2.20 \times 10^{-3} / 8.31 \times 273$ ✓ $n = 0.0970$ (moles) ✓	2
c	(use of mean kinetic energy = $3/2 K T$) $= 3/2 \times 1.38 \times 10^{-23} \times 323$ ✓ 6.69×10^{-21} (J) ✓ 3 sfs ✓	3
d	total internal energy = $6.69 \times 10^{-21} \times 0.0970 \times 6.02 \times 10^{23} = 390$ (J) ✓	1
e	The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. High Level (Good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate provides a comprehensive and coherent sequence of ideas linking the motion of molecules to the pressure they exert on a container. At least three of the first four points listed below must be given in a logical order. The description should also show awareness of how a balance is maintained between the increase in speed and shortening of the time interval between collisions with the wall to maintain a constant pressure. To be in this band, reference must be made to force being the rate of change of momentum or how, in detail, the volume compensates for the increase in temperature. Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate provides a comprehensive list of ideas linking the motion of molecules to the pressure they exert on a container. At least three of the first four points listed below are given. The candidate also knows that the mean square speed of molecules is proportional to temperature. Using this knowledge, an attempt is made to explain how the pressure is constant.	max 6

	Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate attempts the question and refers to at least two of the points listed below. Incorrect, inappropriate or no response: 0 marks No answer or answer refers to unrelated, incorrect or inappropriate physics. Statements expected in a competent answer should include some of the following marking points. molecules are in rapid random motion/many molecules are involved molecules change their momentum or accelerate on collision with the walls reference to Newton's 2nd law either $F = ma$ or $F = \text{rate of change of momentum}$ reference to Newton's 3rd law between molecule and wall relate pressure to force $P = F/A$ mean square speed of molecules is proportional to temperature as temperature increases so does change of momentum or change in velocity compensated for by longer time between collisions as the temperature increases as the volume increases the surface area increases which reduces the pressure	
	Total	14

GCE Physics, Specification A, PHYA5/2A, Astrophysics

Question 1		
a	 mirrors correct – concave primary and convex secondary ✓ both rays correct to eyepiece ✓	2
b i	 diagram to show two pairs of parallel rays being brought to a focus, those further from the axis being focused closer to the mirror ✓	1
b ii	(use of $\theta = \lambda/D$) to give $\theta = 630 \times 10^{-9}/0.15 = 4.2 \times 10^{-6}$ ✓ rad ✓	2
b iii	use of $s = r\theta$ to give $\theta = 4.8 \times 10^3/1.4 \times 10^9 = 3.43 \times 10^{-6}(\text{rad})$ ✓ claim unlikely to be valid as this angle is smaller than the minimum angular separation calculated in ii ✓	2
	Total	7

Question 2		
a	 main sequence curvature correct ✓ giants and (white) dwarfs correct ✓ absolute magnitude scale correct (from 15 to –10) ✓	3
b i	use of $\lambda_{\text{max}} T = 0.0029$ ✓ gives $T = 0.0029/3.4 \times 10^{-7}$ ✓ $= 8.5 \times 10^3 \text{ (K)}$ ✓	3
b ii	use of $P_D/P_S = \sigma A_D T_D^4 / (\sigma A_S T_S^4)$ gives $A_D/A_S = P_D T_S^4 / (P_S T_D^4)$ $= 70000(5700/8500)^4$ $= 1.42 \times 10^4$ ✓ so $r_D/r_S = \sqrt{1.48 \times 10^4} = 119$ ✓ gives $r_D = 119 \times 6.96 \times 10^8 = 8.28 \times 10^{10} \text{ (m)}$ ✓	3

c	The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. High Level (Good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate states that the atmosphere of the star contains hydrogen with electrons in the $n=2$ state and includes a clear description of the absorption process in the atmosphere of the star, with reference to energy jumps corresponding to specific frequencies of light. They describe at least one reason for the gap in the spectrum in terms of the de-excitation process. Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate may not state that electrons start in the $n=2$ state. Only one of the processes, excitation or de-excitation, is satisfactorily described. There should be some link between energy and frequency but they may not make a clear reference to $E=hf$. Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate recognises that changes in electron energy levels are involved. They may confuse absorption for emission and their explanation of why the frequency of the light is important may be vague. They may also be confused between absorption due to the star's atmosphere and the Earth's atmosphere. Incorrect, inappropriate or no response: 0 marks No answer or answer refers to unrelated, incorrect or inappropriate physics.	max 6
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	Statements expected in a competent answer should include some of the following marking points. - the atmosphere of the star has hydrogen atoms with electrons in the $n=2$ state - light from the star passes through the atmosphere of the star - electrons (in the $n=2$) are excited into higher energy states - they can only absorb certain amounts of energy - these certain energies are related to specific frequencies ($E=hf$) - the electrons then de-excite - the electrons may de-excite through different energy level changes - when the electrons de-excite the light is radiated in all directions - this means that the intensity of the light at particular frequencies is reduced, resulting in absorption lines	
	Total	15

Question 3		
a i	increase in wavelength (of em radiation) due to relative recessive velocity between observer and source ✓	1
a ii	use of $v = Hd$ to give $v = 65 \times 25$ ✓ $= 1.6 \times 10^3 (\text{km s}^{-1})$ ✓	2
b i	all type 1a supernovae have same peak absolute magnitude ✓ apparent magnitude can be measured ✓ ref to $m-M \log (d/10)$ or inverse square law ✓	max 2
b ii	use of $m-M = 5 \log (d/10)$ gives $12.9 - (-19.3) = 5 \log (d/10)$ ✓ $\log (d/10) = 6.44$ $d = 27.5 (\text{Mpc})$ ✓	2
c	to make the accepted value for the distance more reliable ✓	1
	Total	8

Question 4		
a	boundary where the escape velocity = c ✓	1
b i	use of $R_s = 2GM/c^2$ to give $R_s = 2 \times 6.67 \times 10^{-11} \times 60 \times 10^6 \times 1.99 \times 10^{30} / (3 \times 10^8)^2$ ✓ $= 1.8 \times 10^{11} \text{ m}$ ✓	2
b ii	use of $D = M/V$ to give $D = 60 \times 10^6 \times 2 \times 10^{30} / (4/3\pi (1.78 \times 10^{11})^3)$ ✓ $= 5.1 \times 10^3 \text{ kg m}^{-3}$ ✓	2
	Total	5
	UMS conversion calculator www.aqa.org.uk/umsconversion	

Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										



General Certificate of Education
Advanced Level Examination
June 2010

Physics A

PHYA5/2A

Unit 5A Astrophysics Section B

Tuesday 29 June 2010 1.30 pm to 3.15 pm

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

For this paper you must have:

- a pencil and a ruler
- a calculator
- a Data and Formulae Booklet.

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.

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.



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WMP/Jun10/PHYA5/2A

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PHYA5/2A

Section B

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

- 1 (a)** Draw a ray diagram for an astronomical refracting telescope in normal adjustment. Your diagram should show the paths of **three** non-axial rays through both lenses. Label the principal foci of the two lenses.

(3 marks)

- 1 (b)** An early form of this telescope was built by Johannes Hevelius. It was 3.7 m long and had an angular magnification of 50. Hevelius used it to help produce one of the earliest maps of the Moon's surface.
- 1 (b) (i)** Calculate the focal lengths of the objective lens and eyepiece lens in an astronomical telescope of length 3.7 m and angular magnification 50.

focal length of objective lens = ... m

focal length of eyepiece lens = ... m

(2 marks)



- 1 (b) (ii) The Triesnecker Crater on the Moon has a diameter of 23 km. Calculate the angle subtended by the image of this crater when viewed through a telescope of angular magnification 50 on the Earth.

distance from Earth to Moon = 3.8×10^5 km

angle = ... rad
(2 marks)

- 1 (c) Early refracting telescopes suffered significantly from chromatic aberration. Draw a diagram to show how a single converging lens produces chromatic aberration.

(2 marks)

9

Turn over for the next question

Turn over ►



- 2** Sirius is a binary system consisting of two stars, Sirius A and Sirius B, the properties of which are summarised below.

	Sirius A	Sirius B
absolute magnitude	1.4	11.2
apparent magnitude	−1.4	8.4
diameter / 10^3 km	2400	12
black-body temperature / K	10 000	25 000

- 2 (a)** Calculate the distance to Sirius, giving an appropriate unit.

distance = ...
(3 marks)

- 2 (b) (i)** Calculate the ratio

$$\frac{\text{power output of Sirius A}}{\text{power output of Sirius B}}$$

ratio = ...
(2 marks)



- 2 (b) (ii)** Show that data in the table suggests that one star is about 8000 times brighter than the other.

.....

.....

.....

(2 marks)

- 2 (b) (iii)** With reference to the spectra of the two stars, explain why the value in part **b (ii)** is much greater than the answer to part **b (i)**.

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(3 marks)

10

Turn over for the next question

Turn over ►



3 The Chandra X-ray Observatory was launched into orbit in 1999. It is used to observe hot and turbulent regions of space.

3 (a) Explain why X-ray telescopes need to be in orbit.

.....

 (1 mark)

3 (b) In 2000, the Chandra telescope was used to observe a *black hole* in Ursa Major.

3 (b) (i) Explain what is meant by a black hole.

.....

 (1 mark)

3 (b) (ii) The black hole is believed to have a mass 7 times that of the Sun. Calculate the radius of its event horizon.

$$\text{mass of the Sun} = 2.0 \times 10^{30} \text{ kg}$$

radius = ... m
 (2 marks)

3 (c) Chandra makes use of a charge coupled device (CCD) to detect the X-ray photons. Describe the processes involved in the detection of photons by a CCD.

.....

 (3 marks)



- 4 (a)** In 1997 a type 1a *supernova* was observed which contributed to the controversial conclusion that the expansion of the Universe is accelerating.

Explain why observations of supernovae led to the conclusion that the Universe is expanding at an accelerating rate and discuss why this conclusion is controversial.

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

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(6 marks)

Question 4 continues on the next page

Turn over ►



4 (b) Measurements of the shift in the 21 cm H1 line in the spectrum of galaxy M84 suggests that it is receding at a velocity of 900 km s^{-1} .

4 (b) (i) Calculate the value of the red shift, z , for this galaxy.

.....

.....

.....

$z =$
(1 mark)

4 (b) (ii) Calculate the distance to this galaxy.

.....

.....

.....

distance = ... Mpc
(2 marks)

END OF QUESTIONS





**General Certificate of Education
June 2010**

Physics A

PHYA5/2A

Astrophysics

Unit 5

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation meeting attended by all examiners and is the scheme which was used by them in this examination. The standardisation meeting ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for the standardisation meeting each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed at the meeting and legislated for. If, after this meeting, examiners encounter unusual answers which have not been discussed at the meeting they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this Mark Scheme are available to download from the AQA Website: www.aqa.org.uk

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Instructions to Examiners

- 1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors, specific instructions are given in the marking scheme.
- 2 Do not deduct marks for poor written communication. Refer the scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (eg relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (ie in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

QWC	descriptor	mark range
Good - Excellent	<i>see specific mark scheme</i>	5-6
Modest - Adequate	<i>see specific mark scheme</i>	3-4
Poor - Limited	<i>see specific mark scheme</i>	1-2
The description and/or explanation expected in a good answer should include a coherent account of the following points: <i>see specific mark scheme</i>		

Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

- 3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks.
- 4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.
- 5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.
- 6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.
- 7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

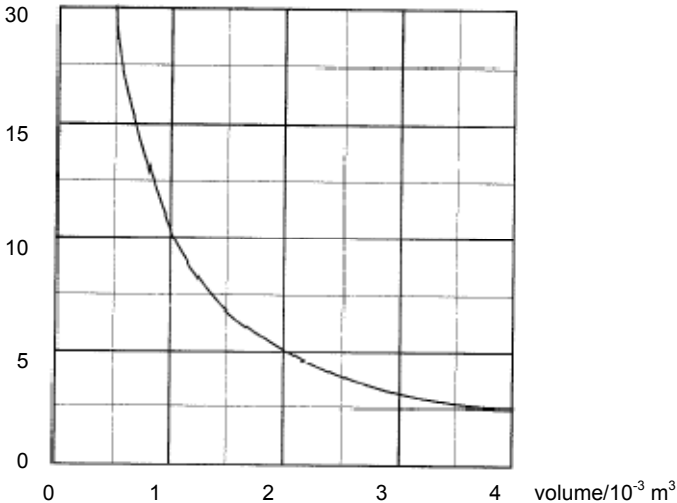
GCE Physics, Specification A, PHYA5/2A, Section A, Nuclear and Thermal Physics

Question 1		
(a)	using $Q = mc\Delta\theta$ $= 3.00 \times 440 \times (84-27) \checkmark$ $7.5 \times 10^4 \text{ (J)} \checkmark$	2
(b)	using $Q = ml$ $= 1.20 \times 2.5 \times 10^4$ $= 3.0 \times 10^4 \text{ (J)} \checkmark$	1
(c)	(heat supplied by lead changing state + heat supplied by cooling lead = heat gained by iron) $3.0 \times 10^4 + \text{heat supplied by cooling lead} = 7.5 \times 10^4 \checkmark$ heat supplied by cooling lead $= 4.5 \times 10^4 = mc\Delta\theta$ $c = 4.5 \times 10^4 / (1.2 \times (327 - 84)) \checkmark$ $c = 154 \text{ (J kg}^{-1} \text{ K}^{-1}) \checkmark$	3
(d)	any one idea $\checkmark$ no allowance has been made for heat loss to the surroundings or the specific heats may not be a constant over the range of temperatures calculated	1
	Total	7

Question 2		
(a)	The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. High Level (Good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate can explain the role of the moderator and control rods in maintaining a critical condition inside the reactor. The explanation is given in a clear sequence of events and the critical condition is defined in terms of neutrons. To obtain the top mark some other detail must be included. Such as, one of the alternative scattering or absorbing possibilities or appropriate reference to critical mass or detailed description of the feedback to adjust the position of the control rods etc. Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate has a clear idea of two of the following: the role of the moderator, the role of the control rods or can explain the critical condition. Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate explains that a released neutron is absorbed by uranium to cause a further fission. Alternatively the candidate may explain one of the following: the role of the moderator, the role of the control rods or can explain the critical condition. The explanation expected could include the following events that could happen to a released neutron. a neutron is slowed by the moderator taking about 50 collisions to reach thermal speeds then absorbed by uranium-235 to cause a fission event one neutron released goes on to cause a further fission is the critical condition a neutron may leave the reactor core without further interaction a neutron could be absorbed by uranium-238 a neutron could be absorbed by a control rod a neutron could be scattered by uranium-238 a neutron could be scattered by uranium-235	max 6

(b)	it is easy to stay out of range or easy to contain an α source or β/γ have greater range/are more difficult to screen ✓ most (fission fragments) are (more) radioactive/unstable ✓ and are initially most likely to be beta emitters/(which also) emit γ radiation/are neutron rich/heavy ✓ ionising radiation damages body tissue/is harmful ✓	max 3
	Total	9

Question 3		
(a)	probability of decay per unit time/given time period or fraction of atoms decaying per second or the rate of radioactive decay is proportional to the number of (unstable) nuclei and nuclear decay constant is the constant of proportionality ✓	1
(b)	use of $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$ $T_{\frac{1}{2}} = \ln 2 / 3.84 \times 10^{-12} \text{ s} \checkmark (1.805 \times 10^{11} \text{ s})$ $= (1.805 \times 10^{11} / 3.15 \times 10^7) = 5730 \text{ y} \checkmark$ answer given to 3 sf ✓	3
(c)	number of nuclei = $N = 3.00 \times 10^{23} \times 1/10^{12} \checkmark$ $(= 3.00 \times 10^{11} \text{ nuclei})$ (using $\frac{\Delta N}{\Delta t} = -\lambda N$) rate of decay = $3.84 \times 10^{-12} \times 3.00 \times 10^{11} \checkmark$ $(= 1.15 \text{ Bq})$	2
(d)	$(N = N_0 e^{-\lambda t}$ and activity is proportional to the number of nuclei $A \propto N$ use of $A = A_0 e^{-\lambda t}$) $0.65 = 1.15 \times e^{-3.84 \times 10^{-12} t} \checkmark$ $t = \frac{\ln(\frac{1.15}{0.65})}{3.84 \times 10^{-12}}$ or $\frac{\ln(\frac{0.651}{1.15})}{-3.84 \times 10^{-12}} \checkmark$ $t = 4720 \text{ y} \checkmark$	3
(e)	the boat may have been made with the wood some time after the tree was cut down the background activity is high compared to the observed count rates the count rates are low or sample size/mass is small or there is statistical variation in the recorded results possible contamination uncertainty in the ratio of carbon-14 in carbon thousands of years ago any two ✓✓	2
	Total	11

Question 4														
(a)	pressure/10^4 Pa  curve with decreasing negative gradient that passes through the given point which does not touch the x axis ✓ <table border="1" data-bbox="410 952 873 1272"><thead><tr><th colspan="2">designated points</th></tr><tr><th>pressure/10^4 Pa</th><th>volume/10^{-3} m³</th></tr></thead><tbody><tr><td>10</td><td>1.0</td></tr><tr><td>5.0</td><td>2.0</td></tr><tr><td>4.0</td><td>2.5</td></tr><tr><td>2.5</td><td>4.0</td></tr></tbody></table> 2 of the designated points ✓✓ (one mark each)	designated points		pressure/ 10^4 Pa	volume/ 10^{-3} m ³	10	1.0	5.0	2.0	4.0	2.5	2.5	4.0	3
designated points														
pressure/ 10^4 Pa	volume/ 10^{-3} m ³													
10	1.0													
5.0	2.0													
4.0	2.5													
2.5	4.0													
(b) (i)	$N = PV/kT = 5 \times 10^4 \times 2 \times 10^{-3} / 1.38 \times 10^{-23} \times 290$ ✓ [or alternative use of $PV = nRT$ $5 \times 10^4 \times 2.0 \times 10^{-3} / 8.31 \times 290 = 0.0415$ moles] $= 2.50 \times 10^{22}$ molecules ✓	2												
(b) (ii)	(mean) kinetic energy of a molecule $= \frac{3}{2}kT = \frac{3}{2} \times 1.38 \times 10^{-23} \times 290$ ✓ ($= 6.00 \times 10^{-21}$ J) (total kinetic energy = mean kinetic energy $\times N$) $= 6.00 \times 10^{-21} \times 2.50 \times 10^{22}$ ✓ $= 150$ (J) ✓	3												

(c)	all molecules/atoms are identical molecules/atoms are in random motion Newtonian mechanics apply gas contains a large number of molecules the volume of gas molecules is negligible (compared to the volume occupied by the gas) or reference to point masses no force act between molecules except during collisions or the speed/velocity is constant between collisions or motion is in a straight line between collisions collisions are elastic or kinetic energy is conserved and of negligible duration any 4 ✓✓✓✓	max 4
	Total	12

GCE Physics, Specification A, PHYA5/2A, Section B, Astrophysics

Question 1		
(a)	3 parallel off-axis rays through objective lens correct ✓ rays continued through to the eyepiece emerging parallel to construction line ✓ correct position of labelled foci ✓	3
(b) (i)	use of $f_o + f_e = 3.7$ and $f_o/f_e = 50$ (to give $51f_e = 3.7$) ✓ $f_o = 3.6$ (m) and $f_e = 0.074$ (m) ✓	2
(b) (ii)	use of $s = r\theta$ to give $\theta = 23/380000 = 6(.053) \times 10^{-5}$ rad ✓ use of $M = \theta_2/\theta_1$ to give $\theta_2 = 50 \times \theta_1 = 3(.026) \times 10^{-3}$ (rad) ✓	2
(c)	diagram to show dispersion of different colours in the correct order ✓ rays crossing each other or principal axis correctly ✓	2
Total		9

Question 2		
(a)	use of $m-M = 5 \log (d/10)$ ✓ to give $-2.8 = 5 \log (d/10)$ ✓ and therefore $d = 2.75$ pc ✓	3
(b) (i)	use of $PA/PB = \sigma A_a T_a^4 / (\sigma A_b T_b^4)$ gives $PA/PB = (2400/12)^2 (10000/25000)^4$ ✓ $= 1(.024) \times 10^3$ ✓	2
(b) (ii)	difference in apparent (or absolute) magnitude = 9.8 ✓ so difference in brightness = $2.5^{9.8}$ $= 7.9(4) \times 10^3$ ✓	2
(b) (iii)	the spectrum of a star is related to its temperature ✓ hotter stars produce a lot of power outside the visible region ✓ the absolute (or apparent) magnitude refers to brightness – the visible region of the spectrum ✓	3
Total		10

Question 3		
(a)	x-rays are absorbed by the Earth's atmosphere ✓	1
(b) (i)	an object whose escape velocity is greater than the speed of light ✓	1
(b) (ii)	use of $R_s = 2GM/c^2$ to give $R_s = 2 \times 6.67 \times 10^{-11} \times 7 \times 2 \times 10^{30} / (3 \times 10^8)^2$ ✓ $= 2.08 \times 10^4 \text{ (m)}$ ✓	2
(c)	CCD consists of silicon (chip) ✓ incident photons cause electrons to be released ✓ electrons are trapped in potential wells in the CCD ✓	3
Total		7

Question 4		
(a)	The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. High Level (Good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate states that the distance an object is away can be determined if its absolute magnitude is known and its apparent magnitude is measured. The candidate also gives a statement that the absolute magnitudes of some supernovae is known and that evidence shows that the Universe is expanding at a faster rate than when the supernovae were produced. Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate states that the distance to some supernovae can be determined, but the reasoning is much more limited. There is a statement that there is evidence that suggests that the expansion of the Universe is accelerating and that there is a controversy, but they may not recognise that Hubble's Law shows that the supernovae should be brighter (ie closer). Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate recognises that there is a controversy about the expansion of the Universe. They may confuse the two methods of determining distance and their explanation of why there is evidence for an accelerating Universe may be vague. The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case. • the absolute magnitude of (some) supernovae is known, this allows supernovae to be used as standard candles • using the inverse square law (or from values of absolute magnitudes) allows the distance to be calculated • supernovae are very bright – so they can be seen in very distant galaxies • it has taken billions of years for the light from the most distant galaxies to reach Earth; these supernovae were therefore produced when the Universe was young • measurement of red shift (to measure velocity) and use of Hubble's Law shows that these supernovae are fainter than expected • this indicates that the Universe is expanding faster now than when the supernovae exploded as the light has had to travel further to reach us than expected by a constant rate of expansion	max 6

(b)	(i)	use of $z = v/c$ to give $z = 900 \times 10^3 / 3 \times 10^8$ $= 3(.00) \times 10^{-3} \checkmark$	1
(b)	(ii)	use of $v = Hd$ to give $d = v/H$ $= 900/65 \checkmark$ $= 13.8 \checkmark$	2
		Total	9