**Astrophysics Practise Questions and Answers**

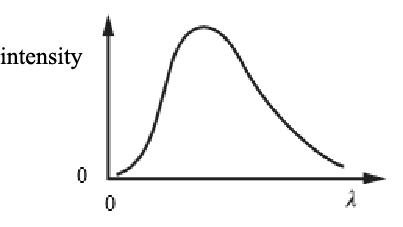
**1.** Betelgeuse is a star in the constellation of Orion which astronomers think could undergo a supernova explosion.  
  
What could Betelgeuse evolve into following the supernova stage?

1. main sequence star
2. neutron star
3. planetary nebulae
4. red giant star

Your answer  

**[1]**

**2.** Stars emit electromagnetic radiation. A graph of intensity against wavelength λ for a main sequence star is shown.



Which statement is correct as the main sequence star evolves into a red giant?

1. the peak wavelength does not change
2. the peak wavelength moves towards the origin
3. the peak wavelength moves to the left
4. the peak wavelength moves to the right

Your answer  

**[1]**

**3.** When the light from a star is passed through a diffraction grating it forms a spectrum.  
  
Which of the following statements is / are correct?

1. Light emitted from the surface of a star would form a continuous spectrum.
2. Light received from the Sun has dark lines across its spectrum which correspond to the absorption of certain wavelengths by atoms in the Earth’s atmosphere.
3. A photon in an emission spectrum occurs when an electron moves from a low to a higher energy level within an atom.
4. 1, 2 and 3
5. Only 1 and 2
6. Only 2 and 3
7. Only 1

Your answer  

**[1]**

**4.** A star has surface temperature 3000 °C and luminosity L. Another star of identical size has a surface temperature of 2500 °C.  
  
What is the luminosity of this second star in terms of L?

1. 0.48L
2. 0.52L
3. 0.83L
4. 0.85L

Your answer  

**[1]**

**5.** A hot metal emits a black-body spectrum. The luminosity of the metal at 800 °C is L.  
  
What is the luminosity of the metal when at 1000 °C?

1. 1.2L
2. 1.3L
3. 2.0L
4. 2.4L

Your answer  

**[1]**

**6.** Which is the most likely evolution of a star which is 10 times more massive than our Sun?

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| A.﻿ main sequence star | → | red supergiant | → | white dwarf | → | black dwarf |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| B. main sequence star | → | supernova | → | red supergiant | → | neutron star |

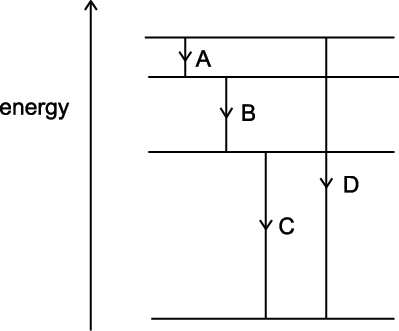
|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| C. main sequence star | → | red supergiant | → | supernova | → | neutron star |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| D. main sequence star | → | red giant | → | neutron star | → | black hole |

Your answer  

**[1]**

**7.** The four energy levels of an atom are shown below.  
Four electron transitions are shown by the arrows **A, B, C** and **D.**



Which electron transition will give the longest wavelength of electromagnetic radiation?  
Your answer  

**[1]**

**8.** Which of the following is the greatest astronomical distance?

1. 1.0 pc
2. 2.0 ly
3. 3.0 × 105 AU
4. 4.0 × 1013 km

Your answer  

**[1]**

**9.** State Hubble’s law.

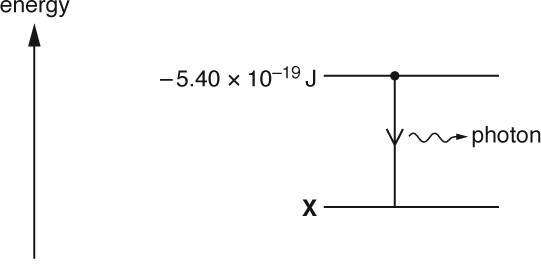
**[1]**

**10.** The intensity against wavelength graph of an object at 750°C peaks at a wavelength of λ. The temperature of the object is raised to 960°C.  
  
What is the wavelength now at the new peak intensity in terms of λ?

|  |  |
| --- | --- |
| **A** | 0.78 λ |
| **B** | 0.83 λ |
| **C** | 1.2 λ |
| **D** | 1.3 λ |

|  |  |  |
| --- | --- | --- |
| Your answer |  | **[1]** |

**11.** An electron makes a transition between the two energy levels shown below.



This transition produces a photon of frequency 4.10 × 1014 Hz.  
  
What is the value of the energy level **X**?

|  |  |
| --- | --- |
| **A** | – 2.68 × 10–19 J |
| **B** | – 2.72 × 10–19 J |
| **C** | – 5.40 × 10–19 J |
| **D** | – 8.12 × 10–19 J |

|  |  |  |
| --- | --- | --- |
| Your answer |  | **[1]** |

**12.** Which two quantities are related in Hubble’s law?

|  |  |
| --- | --- |
| **A** | Distance and mass of galaxies. |
| **B** | Velocity and intensity of galaxies. |
| **C** | Distance and velocity of galaxies. |
| **D** | Distance and red shift of stars in our galaxy. |

|  |  |  |
| --- | --- | --- |
| Your answer |  | **[1]** |

**13.** An astronomer analyses the light from a distant galaxy.  
One of the spectral lines in the spectrum observed from the galaxy has wavelength 610 nm.  
The same spectral line has a wavelength of 590 nm when measured in the laboratory.  
  
What is the speed of this galaxy?

|  |  |
| --- | --- |
| **A** | 9.8 × 106 ms−1 |
| **B** | 1.0 × 107 ms−1 |
| **C** | 2.9 × 108 ms−1 |
| **D** | 3.0 × 108 ms−1 |

|  |  |  |
| --- | --- | --- |
| Your answer |  | **[1]** |

**14.** Some stars will evolve into white dwarfs.  
The mass of the Sun is 2.0 × 1030 kg.  
  
Which of the following **cannot** be the mass of a white dwarf?

|  |  |
| --- | --- |
| **A** | 1.2 × 1030 kg |
| **B** | 2.0 × 1030 kg |
| **C** | 2.7 × 1030 kg |
| **D** | 3.2 × 1030 kg |

|  |  |  |
| --- | --- | --- |
| Your answer |  | **[1]** |

**15.** Recent analysis of the data collected from the Hubble and Gaia telescopes gave the Hubble constant a value of 73.5 km s–1 Mpc–1.  
  
What is this value, written to 2 significant figures, in s–1?

|  |  |
| --- | --- |
| A | 2.4 × 10–21 s–1 |
| B | 2.4 × 10–18 s–1 |
| C | 2.4 × 10–12 s–1 |
| D | 2.4 × 1021 s–1 |

|  |  |  |
| --- | --- | --- |
| Your answer |  | **[1]** |

**16.** In astronomy, distance can be measured in different units.  
  
Which one of the following distances is the **largest**?

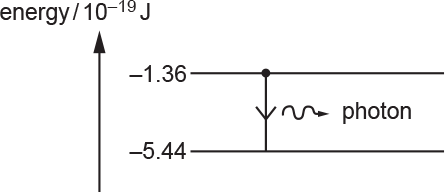
|  |  |
| --- | --- |
| A | 4.22 × 1016 m |
| B | 1.91 pc |
| C | 3.42 ly |
| D | 593AU |

|  |  |  |
| --- | --- | --- |
| Your answer |  | **[1]** |

**17.** Which column **A**, **B**, **C** or **D**, shows the correct sequence for the evolution of the Universe between the Big Bang and the formation of stars?

|  |
| --- |
|  |

|  |  |  |
| --- | --- | --- |
| Your answer |  | **[1]** |

**18.** The diagram below shows two energy levels for the electron in the hydrogen atom.  
  
  
  
  
The electron makes the transition shown by the arrow.  
  
What is the wavelength of the photon emitted?

|  |  |
| --- | --- |
| A | 293 nm |
| B | 366 nm |
| C | 488 nm |
| D | 1460 nm |

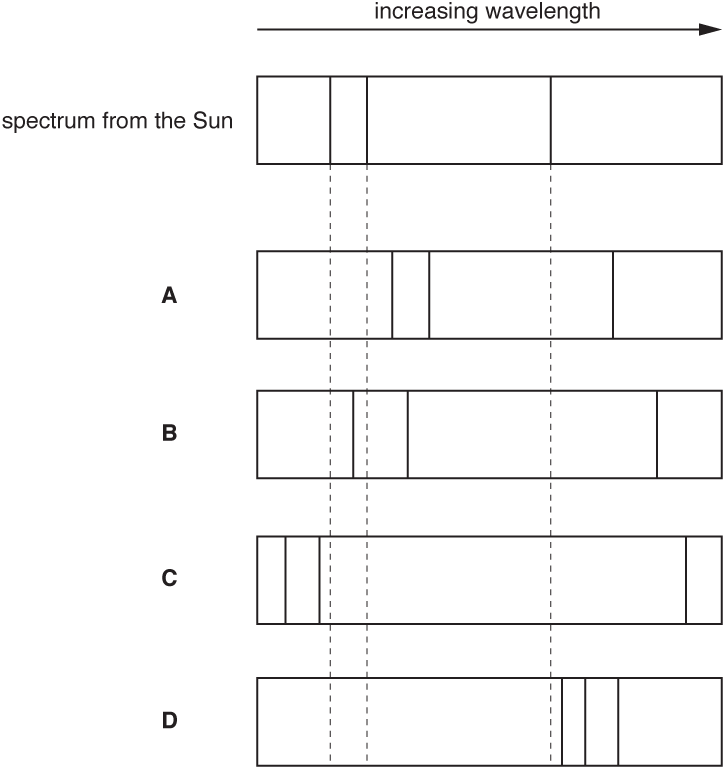
|  |  |  |
| --- | --- | --- |
| Your answer |  | **[1]** |

**19.** Laser light of wavelength of 640 nm is incident normally at a diffraction grating. The separation between adjacent lines (slits) is 3.3 × 10–6 m.  
  
What is the **total** number of bright spots that can be observed in the diffraction pattern?

|  |  |
| --- | --- |
| A | 5 |
| B | 6 |
| C | 10 |
| D | 11 |

|  |  |  |
| --- | --- | --- |
| Your answer |  | **[1]** |

**20.** Part of the line spectrum for light from the Sun is shown below.  
  
Which spectrum best shows light from a similar star to the Sun?



|  |  |  |
| --- | --- | --- |
| Your answer |  | **[1]** |

**21(a).** State and explain how stellar parallax is used to measure distances in space.

**[3]**

**(b).** **Fig. 23.1** gives some data on the wavelength of a hydrogen spectral line for light received from the Andromeda galaxy and the Virgo cluster of galaxies.

|  |  |  |
| --- | --- | --- |
|  | wavelength of hydrogen line from galaxy / nm | wavelength of hydrogen line on Earth / nm |
| Andromeda galaxy | 485.6 | 486.1 |
| Virgo cluster | 489.8 | 486.1 |

**Fig. 23.1**

1. The Virgo cluster is 16.5 Mpc from the Earth.  
     
   Estimate the age of the Universe using data from **Fig. 23.1**.

age = ............................. s    **[3]**

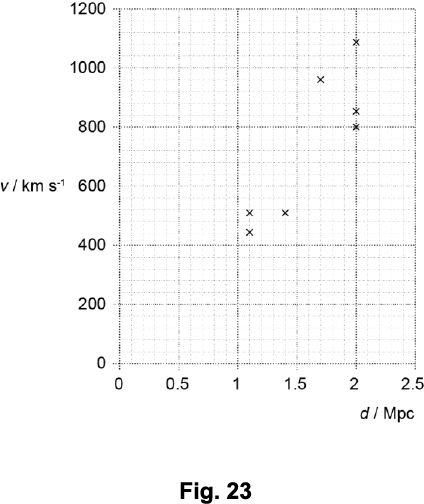
1. Suggest why hydrogen spectral lines might often be used to measure a star’s velocity.

**[2]**

**(c).** \* The Big Bang theory is an explanation for the start of the Universe.  
  
Explain how the cosmic microwave background radiation supports the Big Bang theory for the start of the Universe. Comment on the relevance of the data in **Fig. 23.1** concerning the Big Bang theory.

**[6]**

**22(a).** Hubble’s law can be used to estimate the age of the universe. Fig. 23 shows some of Hubble’s early measurements of nearby galaxies plotted on a v against d graph, where v is the recessional speed of a galaxy and d is its distance from us.



1. State how v was determined.

**[1]**

1. Use Fig. 23 to estimate a value for the Hubble constant H0 in km s−1 Mpc−1.

H0 = ............................................km s−1 Mpc−1 **[3]**

1. Use your answer to part **(ii)** to estimate Hubble’s initial value for the age of the universe in years.

age = ...........................................................years  **[3]**

**(b).** Hubble’s law can be used to estimate the age of the universe. Fig. 23 shows some of Hubble’s early measurements of nearby galaxies plotted on a v against d graph, where v is the recessional speed of a galaxy and d is its distance from us. Measurements of more distant galaxies taken over the last 85 years have refined the value of H0 to be 68 km s1 Mpc−1.

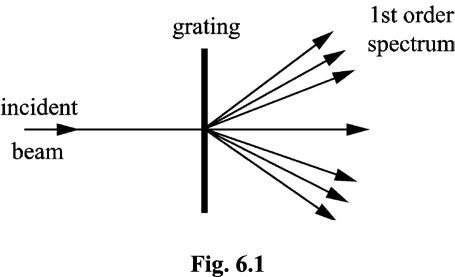
1. Suggest why measurements for our nearest galaxies can deviate from the current Hubble’s law trend line.

**[1]**

1. Suggest why measurements for galaxies at the largest distances deviate from the Hubble’s law trend line.

**[1]**

**23(a).** An astronomer uses a spectrometer and diffraction grating to view a hydrogen emission spectrum from a star. The light is incident normally on the grating.



First order diffraction maxima are observed at angles of 12.5°, 14.0° and 19.0° to the direction of the incident light as shown in **Fig. 6.1.**  
Two of the wavelengths are 4.33 × 10−7 m and 4.84 × 10−7 m.  
Calculate the wavelength of the third line.

wavelength = .......................................... m **[2]**

**(b).** In order to increase the accuracy of the values for wavelength, the student decides to look for higher order diffraction maxima.

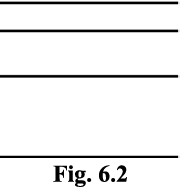
1. State how this increases the accuracy.

**[1]**

1. Calculate how many orders *n* can be observed for the shorter wavelength given in **(a)**.

*n* = .......................................... **[2]**

**(c).** These three emission lines all arise from transitions to the same final energy level. The part of the energy level diagram of hydrogen relevant to these transitions is shown in **Fig. 6.2**.



1. Draw lines between the energy levels to indicate the transitions which cause the three emission lines and label them with their wavelengths.

**[1]**

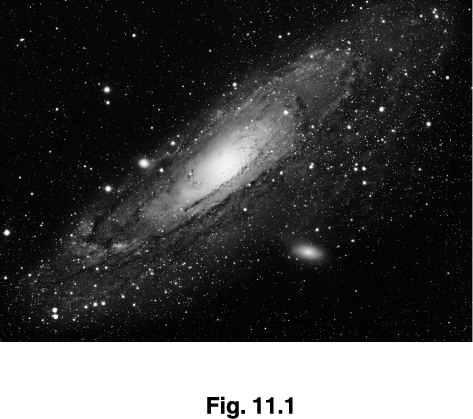
1. There are other possible transitions between the energy levels shown in **Fig. 6.2**. The least energetic of these produces photons of 4.8 × 10−20 J.  
     
   Calculate the wavelength of these photons.  
     
   State in which region of the electromagnetic spectrum this wavelength is found.

wavelength .......................................... m

region: ........................................................................................

**[3]**

**24(a).** Fig. 11.1 shows a diagram of Andromeda, our nearest galaxy.



Andromeda is 2.4 × 1022 m from the Earth. It has a diameter of 1.3 × 1020 m.  
  
Calculate the maximum angle in degrees subtended by Andromeda at the Earth.

angle = ........................................................... ° **[1]**

**(b).** All the stars in Andromeda rotate about its centre. Some stars in Andromeda are moving towards us and some are moving away from us. The outermost stars in Andromeda have a rotational speed of 2.5 × 105 m s−1.  
The wavelength of the hydrogen-alpha spectral line in the laboratory is 656.3 nm. The wavelength of this spectral line from the outermost stars is Doppler shifted when observed from the Earth.  
Calculate the change in wavelength of this spectral line due to this rotation.

change in wavelength = ........................................................... nm **[2]**

**(c).** The circular motion of the outermost stars is due to the gravitational attraction of all the stars in Andromeda. Assume that the mass of Andromeda providing the gravitational force on these outermost stars is all at the centre of this galaxy.  
The average mass of a star is 2.0 × 1030 kg.  
Estimate the total number of stars in Andromeda.

number of stars = ........................................................... **[4]**

**25.** Describe the evolution of the Universe from the separation of the four fundamental forces to the formation of atoms.  
In your answer, you should make clear how the steps of the process are sequenced.

**[5]**

**26(a).** \*The Big Bang theory explains the origin and the evolution of the early Universe.  
The table below shows the distance d and recession velocity v of some galaxies close to our own galaxy.

|  |  |  |
| --- | --- | --- |
| **Galaxy** | **d / Mpc** | **v / km s−1** |
| **NGC-5357** | 0.45 | 200 |
| **NGC-3627** | 0.90 | 650 |
| **NGC-4151** | 1.7 | 960 |
| **NGC-4472** | 2.0 | 850 |

Discuss the evidence for the Big Bang theory of the Universe. Use data in the table and your knowledge of electromagnetic radiation in your answer.  
  
1 pc = 3.1 × 1016 m

**[6]**

**(b).** The chemical composition of the stars in our galaxy can be determined by analysing in the laboratory the absorption spectral lines for these stars.  
The closest star to us is the Sun. The wavelength of the hydrogen-beta spectral line from the Sun is 486 nm.

1. Use the information from the table to calculate the **observed** wavelength λ of the hydrogen-beta spectral line from a star in the galaxy NGC-4151.

λ = ........................................................... nm **[3]**

1. A diffraction grating with 800 lines per mm is used to observe and analyse the light from the Sun in the laboratory.  
   A narrow beam of light from the Sun is incident normally at the diffraction grating.  
   Calculate the angle θ between the central beam of light through the grating and the hydrogen-beta spectral line in the **second** order spectrum.

θ = ........................................................... ° **[2]**

**(c).** Other than matter, state what else may be present in the Universe that may affect its density.

**[1]**

**27(a).** A group of students have gathered data on four stars from the Internet. The information is shown in the table below.

|  |  |  |
| --- | --- | --- |
| **Star** | ***T*** / **K** | **λmax /μm** |
| **Antares** | 3.1 × 103 | 9.4 × 10−1 |
| **Zeta** | 3.0 × 104 | 9.7 × 10−2 |
| **Vega** | 9.3 × 103 | 3.1 × 10−1 |
| **OTS-44** | 2.3 × 103 | 1.3 × 100 |

The surface temperature of the star in kelvin is T and λmax is the wavelength of the emitted electromagnetic radiation at which the intensity is maximum.  
  
Analyse and evaluate this data to show whether or not Wien's displacement law is obeyed.

**[2]**

**(b).** A sensor of cross-sectional area 4.0 × 10−4 m2 mounted on a satellite orbiting the Earth is used to gather the electromagnetic radiation from the star Antares.  
Antares is 550 light years from the Earth. The radiant power entering the sensor from Antares is 2.6 × 10−11 W.

1. Calculate the luminosity L of Antares.

L = ........................................................... W **[3]**

1. Use your answer in **(i)** and the data in the table to calculate the radius r of Antares.

r = ........................................................... m **[2]**

1. The mean density of Antares is 4.4 × 10−5kg m−3.  
   Calculate the gravitational field strength g at the surface of Antares.

g = ........................................................... N kg−1**[2]**

**28.** This question is about the brightest wavelength (590 nm) of light from a sodium lamp.  
  
Analysis of the light from the sodium lamp using a diffraction grating shows that there are photons of two different energies at wavelengths 589.0 nm and 589.6 nm.

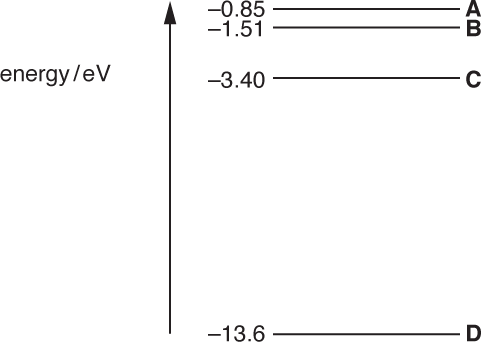
1. Calculate the energy difference ΔE between these two photons.

ΔE = ........................................................... J **[3]**

1. The light at these wavelengths can be seen as two separate lines when viewed through a diffraction grating. In order to be distinguishable from each other, the angular separation between the lines must be at least 0.02°.  
     
   Show that the lines will appear separated in the **second order** spectrum when the sodium lamp is viewed through a grating with 300 lines per millimetre.

**[3]**

**29(a).**    
  
Fig. 21.1 shows some of the energy levels of electrons in hydrogen gas atoms.   
The energy levels are labelled **A**, **B**, **C** and **D**.

  
  
**Fig. 21.1 (not to scale)**

1. Explain why the energy levels are negative.

**[1]**

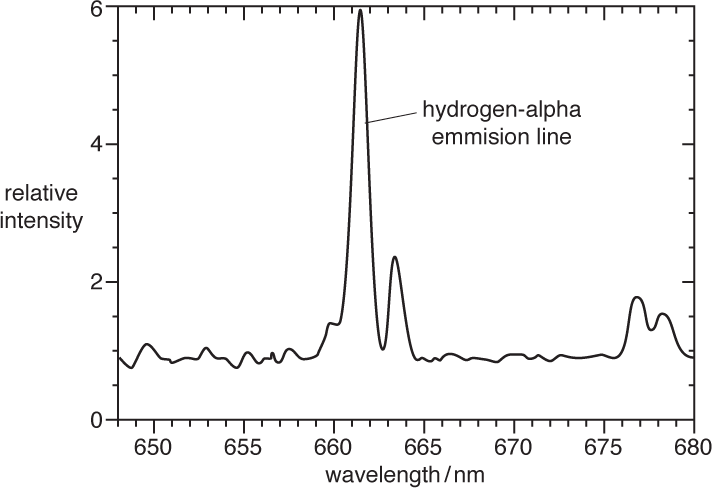
1. An electron makes a transition (jump) from level **C** to level **A**.
   * 1. Calculate the energy gained by this electron.

|  |  |
| --- | --- |
|  | energy = ......................................... eV **[1]** |

* 1. Calculate the wavelength in nm of the photon absorbed by this electron.

|  |  |
| --- | --- |
|  | wavelength = ......................................... nm **[3]** |

**(b).** Light from a distant galaxy is passed through a diffraction grating. Fig. 21.2 shows the part of the spectrum of light that shows a strong hydrogen-alpha emission line.

  
  
**Fig. 21.2**

1. State how an emission line is produced.

**[1]**

1. State an adjustment that could be made to the experimental arrangement that would space the emission lines more widely.

**[1]**

1. In the laboratory, the wavelength of the hydrogen-alpha emission line is 656.3 nm. Use Fig. 21.2 to determine the recession velocity of the galaxy.

|  |  |
| --- | --- |
|  | recession velocity = ......................................... m s−1**[3]** |

1. Suggest why hydrogen spectral lines play an important role in determining red shift of galaxies.

**[1]**

**(c).** Light from a similar star is viewed in a galaxy **further** away. The star is part of a pair of stars which orbit  
a common centre of mass.  
Describe and explain how the equivalent spectrum might appear.

**[3]**

**END OF QUESTION PAPER**

# Mark scheme

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Question** | | | **Answer/Indicative content** | **Marks** | **Guidance** |
| 1 |  |  | B | 1 |  |
|  |  |  | **Total** | **1** |  |
| 2 |  |  | D | 1 |  |
|  |  |  | **Total** | **1** |  |
| 3 |  |  | D | 1 |  |
|  |  |  | **Total** | **1** |  |
| 4 |  |  | B | 1 |  |
|  |  |  | **Total** | **1** |  |
| 5 |  |  | C | 1 |  |
|  |  |  | **Total** | **1** |  |
| 6 |  |  | C | 1 |  |
|  |  |  | **Total** | **1** |  |
| 7 |  |  | A | 1 |  |
|  |  |  | **Total** | **1** |  |
| 8 |  |  | C | 1 |  |
|  |  |  | **Total** | **1** |  |
| 9 |  |  | Recessional speed / velocity of galaxy is proportional to its distance (from us) | B1 |  |
|  |  |  | **Total** | **1** |  |
| 10 |  |  | **B** | 1 | **Examiner’s Comments** This question required the temperatures to be converted into kelvin before finding the peak wavelength, giving option B rather than option A. This question provided opportunities for middle-grade candidates. |
|  |  |  | **Total** | **1** |  |
| 11 |  |  | **D** | **1** | **Examiner’s Comments**  The key to this question is to find the energy of the photon (from E = hf) which gives 2.72 × 10−19 J. The energy level X is this amount of energy below −5.40 × 10−19 J, which can only be answer D. |
|  |  |  | **Total** | **1** |  |
| 12 |  |  | **C** | 1 | **Examiner’s Comments** This question proved particularly straightforward and accessible to nearly all candidates. |
|  |  |  | **Total** | **1** |  |
| 13 |  |  | B | 1 | **Examiner’s Comments**  Option D is the speed of light, so the galaxy cannot be travelling this fast.  The change in wavelength for the galaxy is 20 nm. The laboratory wavelength for this light is 590 nm. The relationship we need is that the fractional change in wavelength for light from a galaxy approximately equals the fraction of the speed of light for that galaxy.  The fractional change in wavelength is 20/590 = 3.39 %  3.39% of the speed of light = 1.02 × 107 m s-1, i.e. option B.  Option A was the most common incorrect response, which is the speed when the change is wavelength is divided by the wavelength of light from the galaxy. |
|  |  |  | **Total** | **1** |  |
| 14 |  |  | D | 1 | **Examiner’s Comments**  The Chandrasekhar limit for the mass of a white dwarf is 1.4 solar masses. The mass of the Sun is 2.0 × 1030 kg, so the mass limit for a white dwarf is 2.8 ×1030 kg. Only star D exceeds this limit, so it cannot be a white dwarf. |
|  |  |  | **Total** | **1** |  |
| 15 |  |  | B | 1 |  |
|  |  |  | **Total** | **1** |  |
| 16 |  |  | B | 1 |  |
|  |  |  | **Total** | **1** |  |
| 17 |  |  | A | 1 |  |
|  |  |  | **Total** | **1** |  |
| 18 |  |  | C | 1 |  |
|  |  |  | **Total** | **1** |  |
| 19 |  |  | D | 1 |  |
|  |  |  | **Total** | **1** |  |
| 20 |  |  | **B** | 1 | **Examiner’s Comments** This question did not discriminate very well at all. The key point is that the emission lines all undergo the same **fractional** wavelength increase, so that the longer wavelengths will have larger absolute increase, as indicated by option B. Option A gives lines which are all the same absolute increase. |
|  |  |  | **Total** | **1** |  |
| 21 | a |  | Apparent motion or displacement of a star relative to the position of more distant stars. | B1 |  |
|  |  |  | Caused by the Earth’s orbit around the Sun. | B1 |  |
|  |  |  | An angle of parallax of 1 arcsecond when displacement of Earth is 1AU corresponds to distance 1 pc | B1 |  |
|  | b | i |  | C1 |  |
|  |  | i |  | C1 |  |
|  |  | i |  | A1 |  |
|  |  | ii | Hydrogen is most common element in stars or Hydrogen has most intense (spectral) lines. | B1 |  |
|  |  | ii | Intensity of light from other elements may be too low for accurate measurement. | B1 |  |
|  | c |  | **\*Level 3 (5–6 marks)** Expect T1 and T2 for the Big Bang Theory Expect full discussion of red shift points R1, 2, 3 and 4 Expect at least B1 and B2 for the Blue Shift Expect C1 and any three from C2, C3, C4, C5 for CMBR  There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.  **Level 2 (3–4 marks)** Expect T1 and T2 for the Big Bang Theory Expect R1 and R2; red shift identified but no explanation why it implies an expanding Universe Expect B1 and B2; blue shift identified with no explanation of cause Expect any three from C1, 2, 3, 4 and 5; CMBR evidence recalled but linked to the Big Bang  There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.  **Level 1 (1–2 marks)** Expect T1 or T2 for the Big Bang Theory Expect R1, R2 or B1, B2; red shift or blue shift identified but without explanation or link to Big Bang Theory Expect at least one from C1, 2, 3, 4 and 5; CMBR evidence recalled but not linked to the Big Bang  The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.  **0 marks** No response or no response worthy of credit. | B1 × 6 | **Big Bang Theory (T)**   1. Predicts that all galaxies will be receding. 2. Galaxy velocity proportional to distance from Earth.   **Red Shift (R)**   1. Radiation from Virgo shows increase in wavelength or red shift 2. Change in wavelength caused by motion of galaxy or reference to Doppler Effect 3. Evidence that Virgo is receding from Earth. 4. Support for Big Bang theory.   **Blue Shift (B)**   1. Andromeda shows blue shift 2. Andromeda approaching Earth 3. Caused by gravitational attraction.   **CMBR (C)**   1. Formed as gamma radiation at Big Bang 2. Galactic red shift to microwave wavelength 3. Intensity is uniform in all directions 4. Corresponds to a temperature of 2.7K 5. (Very small) ripples in intensity corresponding to formation of first stars or galaxies. |
|  |  |  | **Total** | **14** |  |
| 22 | a | i | Velocity determined by Doppler shift of spectral lines | B1 |  |
|  |  | ii | Suitable straight line of best fit though origin | M1 |  |
|  |  | ii | Appropriate pair of values (d, v) taken from line, H0 = v/d | M1 |  |
|  |  | ii | 400 km s−1 Mpc−1 ≤ H0 ≤ 600 km s−1 Mpc−1 | A1 |  |
|  |  | iii | H0 = 500 × 103 / 106 × 3.1 × 1016 = 1.6 × 10−17 s−1 | C1 |  |
|  |  | iii | t = 1 / H0 = 1 / 1.6 × 10−17 = 6.2 × 1016 s | C1 |  |
|  |  | iii | age = 2.0 × 109 (years) | A1 | Accept answers between 1.6 × 109 (years) and 2.5 × 109 (years) CF |
|  | b | i | (Stronger) gravitational attraction between nearby galaxies affects motion / clustering of galaxies | B1 |  |
|  |  | ii | Expansion rate may not have been constant / non-linear expansion / effect of dark energy causing accelerating rate of expansion | B1 |  |
|  |  |  | **Total** | **9** |  |
| 23 | a |  | λ1 = d sin 12.5 = 4.33 × 10−7 m giving 1/d = 5 × 105 or d = 2 × 10−6 | C1 | or λ2 = d sin 14.0 = 4.84 × 10−7 (m) |
|  |  |  | λ3 = sin 19.0/5 × 105 = 6.51 × 10−7 (m)  **or**  λ1 = d sin 12.5 = 4.33 × 10−7 and λ3 = d sin 19.0  so λ3 = 4.33 × 10−7 sin 19.0/sin 12.5 = 6.51 × 10−7 (m) | A1 | or use λ2 = d sin 14.0 = 4.84 × 10−7 m sin 19.0/sin 12.5 = 0.326/0.216 = 1.50 |
|  | b | i | the uncertainty in the measurement of angle is the same for all angles and the bigger the angle measured the smaller the % error | B1 |  |
|  |  | ii | nmax = d sin 90 | C1 |  |
|  |  | ii | = 1/(5 × 105 × 4.33 × 10−7) = 4.6 but n is an integer so n = 4 | A1 |  |
|  | c | i | 3 downward arrows correctly labelled. | B1 | longest being 4.33 × 10−7 (m) |
|  |  | ii | ΔE = hc/λ | C1 |  |
|  |  | ii | λ = 6.63 × 10−34 × 3 × 108/ 4.8 × 10−20 = 4.1(4) × 10−6 (m) | A1 |  |
|  |  | ii | region: infra red | B1 | **allow** ecf if wavelength calculation incorrect. |
|  |  |  | **Total** | **9** |  |
| 24 | a |  | angle = tan −1 (1.3× 1020 / 24 × 1022 ) angle = 0.31 (°) | B1 | **Note**: Using sin−1 is correct; it gives the same answer of 0.31°  **Examiner's Comments**  Examiners concluded that it was the lack of understanding of the term ‘subtended’ in the question that caused confusion. Only a third of the candidates used simple trigonometry to arrive at the correct answer of 0.31°. Some of the answers were very large, e.g. 89°. Such an angle did not register as being unrealistic. |
|  | b |  | (Any subject) | C1 |  |
|  |  |  | Δλ = 0.55(nm) | A1 | **Note**: Answer to 3 sf is 0.547 (nm) **Note**: 5.5 × 10−10 on the answer line scores 1 mark  **Examiner's Comments**  This was another confidently tackled question. The Doppler equation was used well, with most answers for the change in wavelength given in nm. A very small number of candidates struggled to convert their answer of 5.5 × 10−10 m into nm. |
|  | c |  |  |  | **Allow** other correct methods.  **Allow** the following for the first two C1 marks:  *F* =   or 1.92 × 1021 (N) C1  (Any subject) C1 |
|  |  |  | or | C1 |  |
|  |  |  | = (2.5 × 105)2 (any subject) | C1 |  |
|  |  |  | mass = 6.09 × 1040 (kg)  (number of stars = 6.09 × 1040/2.0 × 1030) | C1 | **Allow**: 2 out of 3 marks for use of 1.3 × 1020 (m); this gives an answer of 1.2 × 1041 (kg) |
|  |  |  | number of stars = 3.0 × 1010 | A1 | Possible ECF from incorrect mass of galaxy **Allow** 1 SF answer for the estimation  **Examiner's Comments**  The modal mark for this question was four and about a third of the candidates scored nothing for their work. A range of methods were used to arrive at the correct answer of 3.0 × 1010 stars in the Andromeda galaxy. The most popular route was starting off with the expression  . A significant number of  candidates also successfully used the equation for Kepler's third law. On the whole, candidates demonstrated admirable analytical and calculator skills. |
|  |  |  | **Total** | **7** |  |
| 25 |  |  | Any **four** from: (The forces are separated)  1. Expansion / cooling 2. Creation of matter / pair production 3. More matter than antimatter 4. Quarks and leptons (soup) 5. Quarks combine to form hadrons / baryons / nucleons / protons / neutrons 6. Imbalance of neutrons and protons / (primordial) helium / lithium /beryllium (nuclei) produced 7. Hadrons / baryons / (neutrons and) protons / combine to form nuclei  (Atoms formed) | B1 × 4 |  |
|  |  |  | **QWC**: Correct sequencing of two steps from 4, 5 and 7 | B1 | Annotation by the pencil icon  **Examiner's Comments**  The enthusiasm and knowledge of the evolution of the Universe jumped out from most scripts. The majority of the candidates scored three or more marks. A significant number of candidates used additional answer space to describe the evolution of the Universe after the formation of the atoms. This was not required by the question, but candidates were keen to describe the entire evolution, culminating with the current temperature of 2.7 K. |
|  |  |  | **Total** | **5** |  |
| 26 | a |  | **\*Level 3 (5-6 marks)** Clear use of data and discussion of MBR.  *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.*   **Level 2 (3-4 marks)** Some use of data and discussion of MBR.  *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.*   **Level 1 (1−2 marks)** Limited use of data or limited discussion of MBR.  *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.*  **0 marks** No response or no response worthy of credit. | B1x6 | **Indicative scientific points may include:**    **Use of data**   * The table of values for *d* and *v* support the idea of an expanding Universe. * Calculate of *H*0 more than once using data. * age = *t* =   used correctly to calculate *t*. * Age calculated correctly in s or in y. * Furthest galaxies travelling faster. * Space expanding in all directions. * Use data to plot graph of *v* against *d* to determine *H*0 / graph of *d* against *v* to find *t.* * More data needed since anomalies in the table.   **Discussion of MBR (microwave background radiation)**   * Early Universe extremely hot / very dense. * High energy gamma photons existed in the early Universe. * As space expanded the wavelength of these photons / waves ‘stretched’ out. * We now observe this as microwave background radiation. * Temperature of the Universe is now 2.7 K |
|  | b | i |  | C1 |  |
|  |  | i | Δλ = 1.56 (nm) | C1 |  |
|  |  | i | λ = 486 + 1.56 = 488 (nm) | A1 |  |
|  |  | ii | *d* = 1.25 × 10−6 m | C1 |  |
|  |  | ii | θ = 51° | A1 | **Allow** 1 mark ; incorrect 488 nm used instead of 486 nm. |
|  | c |  | Dark matter / black holes | B1 | **Allow**: anti-matter / dark energy |
|  |  |  | **Total** | **12** |  |
| 27 | a |  | λmax × *T* should be constant if Wien’s law is obeyed. | M1 |  |
|  |  |  | At least data from three stars is used to carry out the test and a clear conclusion. | A1 | **Ignore** POT **Note** λmax × *T* values are 2.91 (× 10−3), 2.91 (× 10−3), 2.88 (× 10−3) and 2.99 (× 10−3) − hence expect ‘*yes the law is obeyed’*. |
|  | b | i | distance = 550 × 9.5 × 1015 (m) | C1 |  |
|  |  | i |  | C1 |  |
|  |  | i | *L* = 2.2 × 1031 (W) | A1 |  |
|  |  | ii |  | C1 | **Possible** ECF from **(i)** **Allow** any subject |
|  |  | ii | *r* = 5.8 × 1011 (m) | A1 |  |
|  |  | iii | mass = 4.4 × 10−5 × 4/3π × (5.8 × 1011)3 | C1 | **Possible** ECF from **(ii)** |
|  |  | iii | *g* = 7.1 × 10−3 (N kg−1) | A1 |  |
|  |  |  | **Total** | **9** |  |
| 28 |  | i | E = hc/λ; Δ*ε* = E1 − E2 = hcΔλ/λ2 | C1 | **allow** calculation of E = hc/λ twice and difference taken |
|  |  | i | Δ*ε* = 6.63 × 10−34 × 3 × 108 × 0.6 × 10−9/ 5.92 × 10−14 | C1 |  |
|  |  | i | Δ*ε* = 3.4 × 10−22 (J) | A1 |  |
|  |  | ii | sin θ = nλ/d; 1/d = 3 × 105 (m−1) | C1 |  |
|  |  | ii | θ1 − θ2 = sin−1 (2 × 589.6 × 3 × 10−4) − sin−1 (2 × 589 × 3 × 10−4) | M1 | **or** similar |
|  |  | ii | θ1 − θ2 = 20.717 − 20. 695 = 0.0220 | A1 | **allow** 20.72 − 20.70 |
|  |  |  | **Total** | **6** |  |
| 29 | a | i | electron bound to nucleus / represents energy electron must gain to leave the atom / total energy of electron in atom is less than that of a free electron | **B1** | **Allow** ionisation level defined as zero as AW for ‘represents electron must gain energy to leave atom / move up energy level’ **Allow** potentials for attractive forces are negative.  **Examiner’s Comments** This item provided good discrimination between the candidates. Many responses referred incompletely to the negative charge of the electron being the only factor, whereas the correct explanation is much more to do with the electron requiring energy to leave the atom and the ionization level being defined as the zero point.  Some candidates were on the right path when they referred to the equivalent statement for gravitational potential energies. |
|  |  | ii | **1** energy = 2.55 (eV) **2** energy = 2.55 × 1.60 × 10−19 (J)    wavelength = 4.9 × 10−7 (m)  wavelength = 490 (nm) | **B1  C1    C1     A1** | Ignore sign Possible ECF from **(ii)1**       **Note:** wavelength = 488 (nm) to 3 sf  **Examiner’s Comments** Virtually all candidates correctly evaluated the energy difference to be 2.55 eV. Negative values were condoned but are unlikely to be accepted in future series.  Many candidates correctly calculated the wavelength of emitted light, although a minority did not convert the energy into joules or performed the required conversion to nanometres incorrectly. |
|  | b | i | Electron(s) makes a transition to a lower (energy) level / loses energy **and** emitting a photon(s) / EM radiation | **B1** | **Examiner’s Comments** Many candidates muddled up emission (lines emitted by a source) and omission (as in lines absorbed by a low pressure gas when a continuous spectrum passes through it, as in an absorption spectrum), so could not score the mark. Some focused on the experimental procedure of using a diffraction grating. A third of candidates correctly stated that the electron dropped down to a lower energy state, releasing a photon or the equally acceptable ‘EM radiation’ |
|  |  | ii | Reduce grating separation / increase distance between grating and screen | **B1** | **Allow** ‘use finer grating’ or ‘use grating with more lines mm−1’ **Not** ‘smaller slit size’  **Examiner’s Comments** This item tested knowledge of specification 5.5.2 (g) and PAG 5. It would be advisable for Centres, where possible, to allow candidates to observe the effect of changing the slit separation and the grating-screen separation independently.  Approximately a third of students correctly suggested making one of those adjustments, even if they expressed the former as ‘increase the number of lines per mm’.  Some candidates presented arguments about plotting the graph on a smaller scale or measuring the wavelength in picometres in an attempt to resolve the peaks in the plot, which was a mis-interpretation of the question. |
|  |  | iii | wavelength (of peak) = 661.5 nm v = 3.0 × 108 × (661.5 − 656.3) / **656.3** recession velocity = 2.4 × 106 (m s−1) | **C1  C1  A1** | **Allow:** between 661 and 662 nm **Note:** check divided by 656.3 nm Range of acceptable answers. 2.1(5)−2.6(1) × 106  **Examiner’s Comments** Examiners were pleased to see this item answered well, with the majority of candidates gaining either two or three marks. Those that did not either misread the position of the red-shifted spectral peak, did not recognise that they were looking for the peak wavelength or did not use the ‘at rest’ wavelength for the denominator of the expression for the change in wavelength. |
|  |  | iv | (Relative) abundance of hydrogen (AW) | **B1** | **Allow** ‘Hydrogen commonly found in stars’ (AW)  **Examiner’s Comments** Just over half of all candidates realised that the useful property of hydrogen was its relative abundance in stars and hence galaxies. |
|  | c |  | Less intense  Galaxy is moving faster **and** therefore greater / longer wavelength (AW)  Periodic shift in wavelength (if plane of orbit is in line of sight) (ORA) | **B1  B1   B1** | **Allow** ‘greater red shift’ / ‘greater Doppler shift’ / ‘to the right’ for longer wavelength  **Allow** argument referring to splitting of line because of relative velocities of two component stars. **Not** idea of blue shift.  **Examiner’s Comments** Some 9% of all candidates declined to answer this item, the highest rate for any item on this paper.  The most common correct response linked higher distance with higher recessional velocity and thus higher increase in wavelength.  Higher ability candidates explained that the orbiting stars would have different velocities relative to the Earth resulting in a periodic change in wavelength from the central peak. References to blue-shifting were erroneous and contradictory. |
|  |  |  | **Total** | **14** |  |