CAMBRIDGE INTERNATIONAL A LEVEL • PHYSICS 9702

Topical Questions

Unit 25: Astrophysics

Past Papers 2021 – 2025

Note: No question in 2021 from Astrophysics

QUESTION PAPER 21 Questions

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Question 1

(a) State what is meant by luminosity of a star.

.....

..... [1]

(b) The luminosity of the Sun is 3.83×10^{26} W. The distance between the Earth and the Sun is 1.51×10^{11} m.

Calculate the radiant flux intensity F of the Sun at the Earth. Give a unit with your answer.

F = ... unit ..... [2]

(c) Use data from **(b)** to calculate the mass that is converted into energy every second in the Sun.

mass = ... kg [1]

(d) The radius of the Sun is 6.96×10^{8} m.

Show that the temperature T of the surface of the Sun is 5770 K.

[1]

(e) The wavelength λ_{max} of light for which the maximum rate of emission occurs from the Sun is 5.00×10^{-7} m.
The temperature of the surface of the star Sirius is 9940 K.

Use information from **(d)** to determine the wavelength of light for which the maximum rate of emission occurs from Sirius.

wavelength = ... m [2]

[Total: 7]

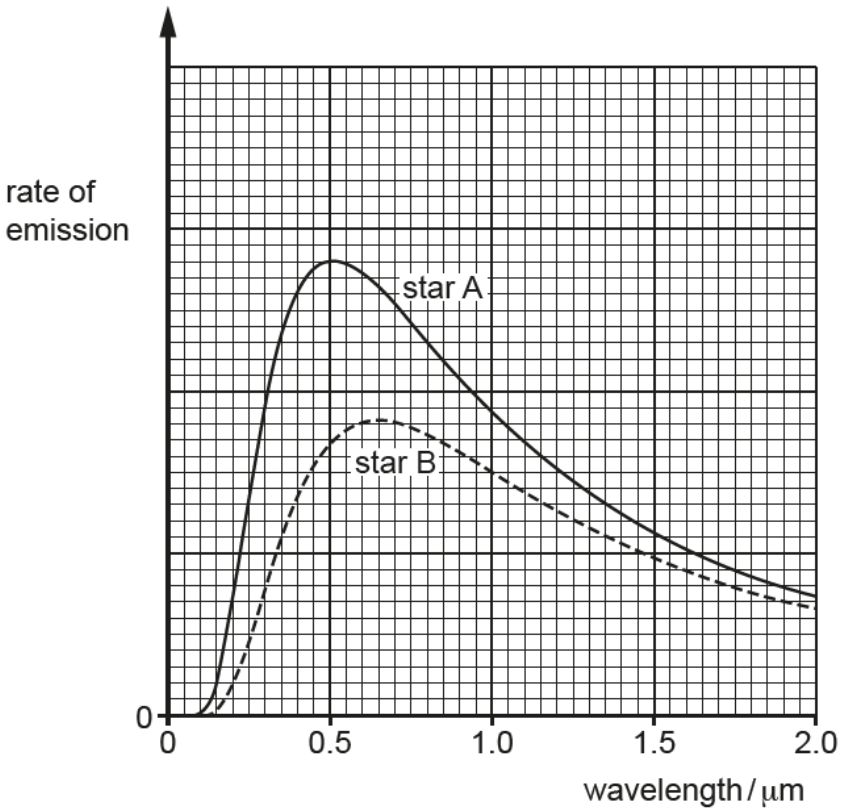
Question 2

(a) State Wien's displacement law.

.....

..... [1]

(b) Fig. 10.1 shows the wavelength distributions of electromagnetic radiation emitted by two stars A and B.



The surface temperature of star A is known to be 5800 K.

(i) Determine the surface temperature of star B.

surface temperature = ... K [2]

(ii) Star B appears less bright than star A when viewed from the Earth.

Use Fig. 10.1 to suggest, with a reason, how else the physical appearance of star B compares with that of star A.

.....

.....

..... [2]

(c) The lines in Fig. 10.1 have been corrected for redshift.

(i) State what is meant by redshift.

.....

.....

..... [2]

(ii) Explain how cosmologists are able to determine that light from a distant star has undergone redshift.

.....

.....

..... [2]

[Total: 9]

Question 3

(a) (i) State Hubble's law.

.....

.....

..... [2]

(ii) Explain how cosmologists use observations of emission spectra from stars in distant galaxies to determine that the Universe is expanding.

.....

.....

.....

..... [2]

(b) Explain how Hubble's law and the idea of the expanding Universe lead to the Big Bang theory of the origin of the Universe.

.....

.....

.....

..... [3]

[Total: 7]

Question 4

(a) State what is meant by the luminosity of a star.

..... [1]

(b) A star in the constellation Canis Major is a distance of 8.14×10^{16} m from the Earth and has a luminosity of 9.86×10^{27} W. The surface temperature of the star is 9830 K.

(i) Calculate the radiant flux intensity of the radiation from the star observed from the Earth. Give a unit with your answer.

radiant flux intensity = ... unit ..... [2]

(ii) Determine the radius of the star.

radius = ... m [2]

c) Explain how the surface temperature of a distant star may be determined from the wavelength spectrum of the light from the star.

.....

.....

.....

..... [3]

[Total: 8]

Question 5

(a) Fig. 9.1 shows the visible part of the emission spectrum from hydrogen gas in a laboratory on the Earth. The numbers indicate the wavelength, in nm, represented by each line.

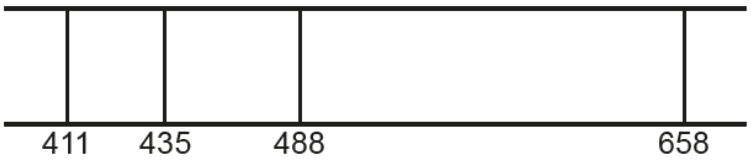


Fig. 9.1

(i) Explain how the emission spectrum provides evidence for the existence of discrete energy levels for the electron in a hydrogen atom.

.....

.....

.....

..... [3]

(b) The same part of the emission spectrum from hydrogen as in **(a)**, observed in light from stars in a distant galaxy, is shown in Fig. 9.3. The numbers indicate the wavelengths in nm.

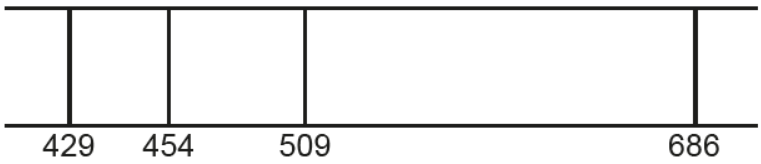


Fig. 9.3

The spectrum shows the same pattern as Fig. 9.1 but with different wavelengths.

(i) State the name of the phenomenon that gives rise to the change in the wavelengths.

..... [1]

(ii) State what this phenomenon shows about the motion of the galaxy.

..... [1]

(iii) Use one of the lines in Fig. 9.1, and the corresponding line in Fig. 9.3, to determine the speed of the distant galaxy relative to the observer.

speed = ... $m\,s^{-1}$ [3]

(c) The galaxy in **(b)** is known to be a distance of 5.7×10^{24} m from the Earth.

Use your answer in **(b)(iii)** to determine a value for the Hubble constant H_0.

H_0 = ... s^{-1} [2]

Question 6

(a) A student observes different stars from the Earth.
Give **two** reasons why some stars appear brighter than others.

1 .....

.....

2 .....

.....
[2]

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

.....

..... [1]

(c) A spectral line from a star within a galaxy is observed to have a wavelength of 660.9 nm. The same spectral line measured in the laboratory is observed to have a wavelength of 656.3 nm.

(i) Show that the speed of the star relative to the Earth is $2.1 \times 10^{6}\,\text{m s}^{-1}$.

[1]

(ii) Calculate the distance to the star.

The Hubble constant is $2.3 \times 10^{-18}\,\text{s}^{-1}$.

distance = ... m [2]

(iii) State and explain what can be concluded about the Universe based on this change in observed wavelength.

.....

.....

.....

.....

..... [3]

[Total: 9]

Question 7

(a) State Hubble's law. Identify any symbols that you use.

.....

.....

.....

..... [2]

(b) A star of luminosity 3.8×10^{31} W is a distance of 1.8×10^{24} m from the Earth.

Calculate the radiant flux intensity at the Earth of the radiation emitted by the star.

radiant flux intensity = ... $W\,m^{-2}$ [2]

(c) The star in **(b)** is in a distant galaxy. A spectral line in the light from this galaxy is known to have a wavelength of 486 nm. This spectral line in the light from the galaxy observed on the Earth has a wavelength of 492 nm.

(i) Explain why the wavelength observed on the Earth is different from the wavelength that the galaxy is known to have emitted.

.....

.....

..... [2]

(ii) Determine a value for the Hubble constant H_0.

H_0 = ... s^{-1} [3]

[Total: 9]

Question 8

(b) The surface of a star consists mainly of a gas that may be assumed to be ideal. The molecules of the gas have a root-mean-square (r.m.s.) speed of 9300 $m\,s^{-1}$.

The mass of a molecule of the gas is 3.34×10^{-27} kg.

Determine, to three significant figures, the temperature of the surface of the star.

temperature = ... K [2]

(c) The radiant flux intensity of the radiation from the star in **(b)** is $2.52 \times 10^{-8}\,W\,m^{-2}$ when observed at a distance of 4.16×10^{16} m from the star.

(i) Calculate the luminosity of the star. Give a unit with your answer.

luminosity = ... unit ..... [2]

(ii) Determine the radius of the star.

radius = ... m [2]

(d) The gas at the surface of a star has a very high pressure.

Use the basic assumptions of the kinetic theory to suggest why, in practice, a gas at the surface of a star is unlikely to behave as an ideal gas.

.....

.....

.....

..... [2]

Question 9

(a) State Wien's displacement law. Identify any symbols that you use.

.....

.....

..... [2]

(b) A cosmology student observes the electromagnetic radiation received from a star in a galaxy. The student uses Wien's law to estimate the surface temperature of the star, a standard candle to estimate the distance to the galaxy, and the Stefan–Boltzmann law to estimate the radius of the star.

The student observes that the radiation from the star is redshifted.

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

..... [1]

(ii) State the reason why the radiation from the star is redshifted.

..... [1]

(iii) The true values of the quantities observed or estimated are those that are corrected to allow for redshift. However, the student does not correct for redshift.

By placing one tick (✓) in each row, complete Table 10.1 to indicate how the observations and estimates made by the student compare with the true values.

Table 10.1

	student's uncorrected value		
	too low	the same	too high
wavelength of radiation			
surface temperature of star			
distance to star			
radius of star			

[4]

[Total: 8]

Question 10

(a) The Sun has a surface temperature of 5780 K. The luminosity of the Sun is 3.85×10^{26} W.

(i) Calculate the radius of the Sun.

radius = ... m [2]

(ii) The Earth is a distance of 1.50×10^{11} m from the Sun.

Calculate the radiant flux intensity F of the radiation from the Sun at a distance of 1.50×10^{11} m. Give a unit with your answer.

F = ... unit ..... [2]

(iii) The variation with wavelength of the intensity of radiation emitted from the Sun is shown in Fig. 10.1.

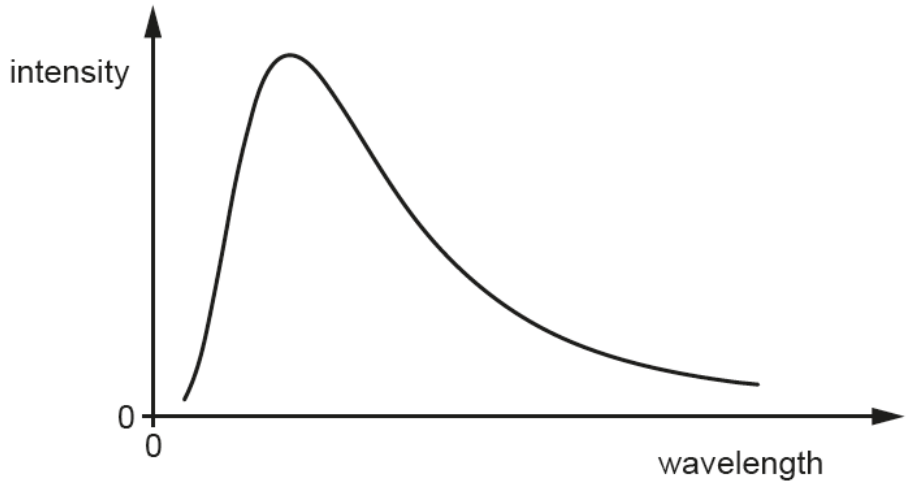


Fig. 10.1

Another star has the same radius as the Sun but has a lower surface temperature.

On Fig. 10.1, sketch a line to show the variation with wavelength of the intensity of the radiation emitted for this star. [2]

(b) A galaxy in the constellation Corona Borealis is moving away from the Earth.

(i) The visible emission spectrum for the Sun is shown in Fig. 10.2.

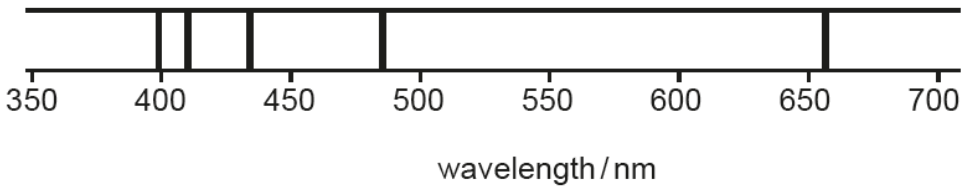


Fig. 10.2

The lines are at wavelengths of 397 nm, 410 nm, 434 nm, 486 nm and 656 nm. The compositions of the Sun and a star in the Corona Borealis galaxy are similar.

On Fig. 10.3, sketch the emission spectrum for the star in the Corona Borealis galaxy as observed from the Earth. No calculations are required.

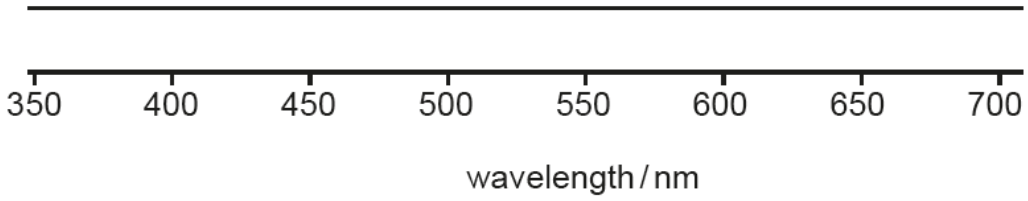


Fig. 10.3

[1]

(ii) The galaxy in Corona Borealis is moving away from the Earth at a speed of 21 400 km s^{-1}.

Use information from **(b)(i)** to calculate, in nm, the observed wavelength of the lowest visible energy emission for the star in the Corona Borealis galaxy.

wavelength = ... nm [2]

(iii) The wavelength in **(b)(ii)** is used to calculate a value for the surface temperature of the star in the Corona Borealis galaxy. The calculation does not give an accurate value.

State and explain whether this value of temperature is too high or too low.

.....

.....

..... [1]

[Total: 10]

Question 11

(a) (i) State what is meant by the luminosity of a star.

.....

.....

..... [2]

(ii) Explain how a standard candle in a distant galaxy can be used to determine the distance of the galaxy from an observer.

.....

.....

.....

.....

..... [3]

(b) The Sun has a radius of 6.96×10^8 m and a surface temperature of 5780 K.
Light from the Sun is observed to have a peak intensity at a wavelength of 501 nm.

(i) Calculate the luminosity of the Sun. Give a unit with your answer.

luminosity = ... unit ..... [2]

(ii) Another star emits radiation that has a peak intensity at a wavelength of 624 nm.

Determine the surface temperature of this star.

surface temperature = ...K [2]

[Total: 9]

Question 12

(a) Explain how redshift leads to the idea that the Universe is expanding.

.....

.....

.....

.....

..... [3]

(b) Stars in a distant galaxy emit radiation. The total luminosity of the stars in the galaxy is 1.90×10^{36} W.
The emission spectrum of the radiation contains a line X at a wavelength of 658 nm.

Radiation from the galaxy is observed on the Earth. The observed radiation has a radiant flux intensity of 8.42×10^{-16} W m^{-2}. In the observed emission spectrum, line X is at a wavelength of 726 nm.

Determine:

(i) the distance d of the galaxy from the Earth

d = ... m [2]

(ii) the speed v of the galaxy relative to the Earth.

v = ... m s^{-1} [2]

(c) Observations of many galaxies, such as the one in **(b)**, lead to many pairs of values of d and v. Plotting these values reveals a trend.

(i) On Fig. 10.1, sketch the variation of v with d.

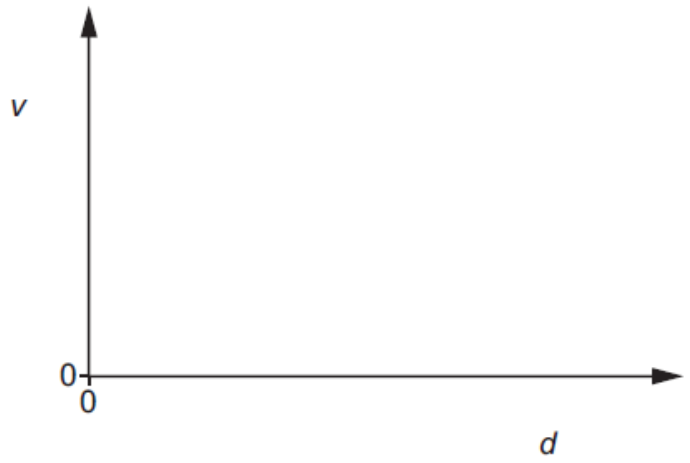


Fig. 10.1

[2]

(ii) State the name of the quantity represented by the gradient of the line in Fig. 10.1.

..... [1]

[Total: 10]

Question 13

(a) (i) State what is meant by the luminosity of a star.

.....

..... [1]

(ii) Explain how standard candles are used to determine the distance to a galaxy.

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.....

.....

.....

.....

..... [3]

(b) The Sun rotates on its axis. Points X, Y and Z are on the equator of the Sun as shown in Fig. 10.1.

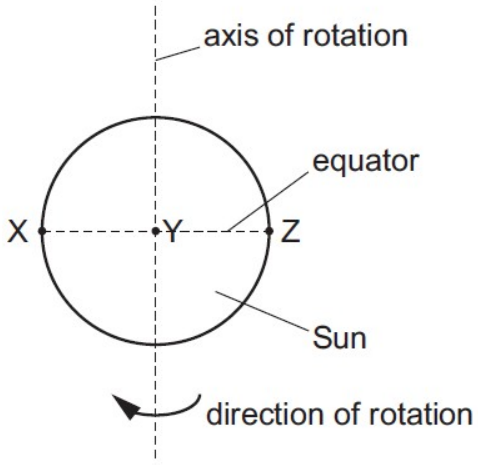


Fig. 10.1

The wavelengths of light from points X and Y are observed and recorded in Table 10.1.

Table 10.1

observed wavelength from X/nm	observed wavelength from Y/nm
656.2877	656.2831

(i) The Sun rotates with a period of 2.07×10^6 s.

Show that the radius of the Sun is 6.93×10^8 m.

[3]

(ii) State and explain how the expected wavelength of the light observed from Z compares with the emitted wavelength.

.....

.....

..... [2]

(iii) The luminosity of the Sun is 3.8×10^{26} W.

Use the information in **(b)(i)** to calculate the surface temperature of the Sun.

temperature = ... K [2]

[Total: 11]

Question 14

(a) State Hubble's law.

.....

.....

..... [2]

(b) A star in a distant galaxy emits radiation that has a maximum intensity of emission at a wavelength of 4.62×10^{-7} m.

Observations of the galaxy made on the Earth detect the maximum intensity of emission from the star at a wavelength of 4.91×10^{-7} m.

(i) Explain why the observed wavelength and the emitted wavelength have different values.

.....

.....

..... [2]

(ii) Calculate the speed of the star relative to the Earth.

speed = ... $m\,s^{-1}$ [2]

(iii) The wavelength of maximum intensity of emission is used to determine a value for the surface temperature of the star.

Explain how the temperature determined using the observed wavelength compares with the true value of temperature determined using the emitted wavelength.

.....

.....

..... [2]

(c) A value for the Hubble constant is $2.3 \times 10^{-18}\,s^{-1}$.

Use your answer in **(b)(ii)** to determine the distance of the star in **(b)** from the Earth.

distance = ... m [2]

[Total: 10]

Question 15

The deuterium nucleus ($^{2}_{1}H$) has a mass defect of 0.002 388 u. The helium-4 nucleus ($^{4}_{2}He$) has a mass defect of 0.030 377 u. Helium-4 is formed from deuterium in a nuclear reaction that can be represented by the equation

$$3\,{}^{2}_{1}H \longrightarrow {}^{4}_{2}He + {}^{1}_{1}p + {}^{1}_{0}n.$$

(a) (i) State the name of this type of nuclear reaction.

..... [1]

(ii) Show that the energy released when one nucleus of helium-4 is formed from deuterium is 3.47×10^{-12} J.

[3]

(b) A star has a radius of 6.96×10^{8} m. Helium-4 is produced in this star, from deuterium, at a mass rate of 7.34×10^{11} kg s^{-1}. All the energy released from this process is radiated away from the star. All the energy that is radiated from the star is released by this process.

(i) Calculate the luminosity of the star.

luminosity = ... W [3]

(ii) Use your answer in **(b)(i)** to determine the surface temperature of the star.

temperature = ... K [2]

[Total: 9]

Question 16

(a) State Wien's displacement law.

.....

.....

..... [2]

(b) Fig. 9.1 shows the variation with d^{-2} of the radiant flux intensity F observed from a star X, where d is the distance of the observer from the star. Fig. 9.2 shows the variation with wavelength λ of the rates of emission P of radiation by star X and the Sun.

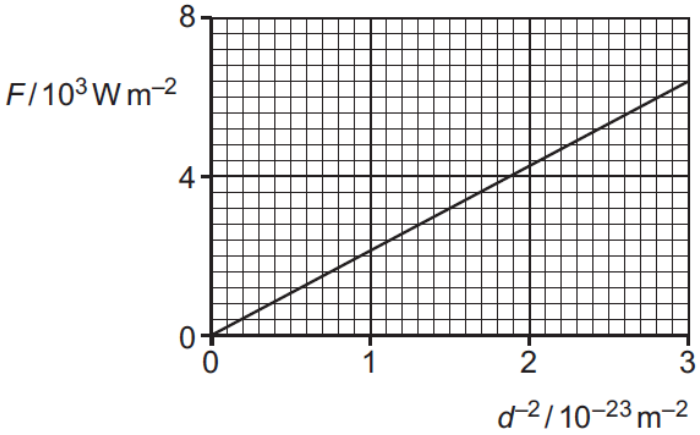


Fig. 9.1

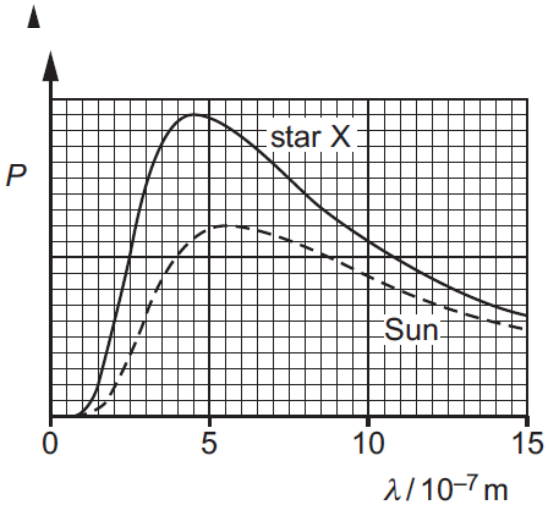


Fig. 9.2

The surface temperature of the Sun is 5770 K.

State **three** conclusions about star X that can be drawn from this data. The conclusions may be qualitative or quantitative. Use the space for any working.

1 .....

.....

2 .....

.....

3 .....

.....

[3]

(c) Star X is in a galaxy that is moving away from the Earth.

Suggest, with a reason, how the line for star X in Fig. 9.2 would appear differently if it had been obtained from data measured on the Earth.

.....

.....

..... [2]

[Total: 7]

Question 17

(b) The nuclear fusion reaction for the formation of helium-4 from deuterium is represented by

$$^{2}_{1}\text{H} + ^{2}_{1}\text{H} \rightarrow ^{4}_{2}\text{He}.$$

Table 9.1 shows the masses of the nuclides involved in this reaction.

Table 9.1

nuclide	nuclide mass / u
$^{2}_{1}\text{H}$	2.013553
$^{4}_{2}\text{He}$	4.001505

Calculate the energy released in the formation of 1.00 mol of helium-4.

energy = ... J [4]

(c) The star Sirius has a radius of 1.19×10^9 m and loses mass due to nuclear fusion at a rate of 1.09×10^{11} kg s^{-1}. Assume that the power of the radiation emitted by the star is equal to the power released by this process.

(i) Determine a value for the luminosity of Sirius. Give a unit with your answer.

luminosity = ... unit ..... [2]

(ii) Use your answer in **(c)(i)** to determine the surface temperature of Sirius.

surface temperature = ... K [2]

(d) Explain how cosmologists use standard candles to estimate the distance of a galaxy from the Earth.

.....

.....

.....

.....

..... [3]

[Total: 13]

Question 18

(a) State what is meant by redshift.

.....

.....

..... [2]

(b) Explain how observations of redshift lead to the idea that the universe is expanding.

.....

.....

..... [2]

(c) Explain how Hubble's law leads to the Big Bang theory of the origin of the universe.

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.....

.....

.....

..... [3]

[Total: 7]

Question 19

A star in a distant galaxy has a known spectral line at wavelength 486 nm when measured in the laboratory. The same line is observed at 502 nm on Earth.

The radiant flux intensity measured at Earth is $3.6\times10^{-15}\,Wm^{-2}$.

The Hubble constant is $2.2\times10^{-18}s^{-1}$.

(a)

(i) Show that the galaxy is receding from Earth. [1]

(ii) Calculate the speed of recession of the galaxy. [2]

(b)

Use Hubble's law to determine the distance of the galaxy from Earth. [2]

(c)

Calculate the luminosity of the star. [2]

(d)

The wavelength of maximum emission from the star (corrected for redshift) is 410 nm.

(i) Determine the surface temperature of the star. [2]

(ii) The star's luminosity is related to its radius by the Stefan–Boltzmann law.
Determine the radius of the star. [3]

Question 20

A star rotates with period $1.9\times10^{6}\,s$.
A spectral line of wavelength 656.3 nm is observed from two opposite edges of the equator:

656.298 nm
656.342 nm

(a) Explain why the wavelengths are different. [2]

(b) Calculate the equatorial speed of the star. [3]

(c) Hence determine the radius of the star. [3]

(d) The star is in a galaxy with redshift $z=0.015$.

State what this indicates about the Universe. [2]

Question 21

(Fusion + Luminosity + Distance + Temperature Bias)

A star converts hydrogen into helium with a mass defect of 0.028 u per reaction.

It produces 9.0×10^{37} reactions per second.

(a) Calculate the luminosity of the star. [3]

(b) If observed flux is $4.5\times10^{-10}\,Wm^{-2}$, determine distance. [2]

(c) The observed peak wavelength is 620 nm but is redshifted by 4%.

d. Explain whether the calculated temperature will be too high or too low if redshift is ignored. [3]

Larger wavelength → smaller calculated temperature

✔️ Temperature will be **too low**