Astrophysics and cosmology – 2021/20 GCE Physics A Component 01

1. Nov/2021/Paper_H556_01/No.5

A spectral line corresponds to a wavelength λ_1 in the laboratory.
The same spectral line observed in the spectrum of a receding galaxy corresponds to a wavelength λ_2.
The distance of the galaxy from the Earth is d. The speed of light in a vacuum is c.

What is the correct expression for the Hubble constant H_0?

A $H_0 \approx \frac{c(\lambda_2 - \lambda_1)}{d\lambda_1}$

B $H_0 \approx \frac{c\lambda_1}{d(\lambda_2 - \lambda_1)}$

C $H_0 \approx \frac{c\lambda_2}{d\lambda_1}$

D $H_0 \approx \frac{c\lambda_1}{d\lambda_2}$

Your answer ☐ **[1]**

2. Nov/2021/Paper_H556_01/No.15

The parallax angle for a star is 0.015 seconds of arc.

What is the distance in parsecs (pc) of the star from the Earth?

A 67 pc

B 133 pc

C 220 pc

D 2.1×10^{18} pc

Your answer ☐ **[1]**

3. Nov/2021/Paper_H556_01/No.23

Algol is a triple-star system, with stars Aa1, Aa2 and Aa3 orbiting each other.
This triple-star is 90 light-years from the Earth.

(a) Here is some data on the star Aa1.

- radius = $(1.90 \pm 0.14) \times 10^{9}$ m
- mass = $(6.31 \pm 0.42) \times 10^{30}$ kg.

Calculate the gravitational field strength g at the surface of Aa1 to **3** significant figures. Include the absolute uncertainty in your answer. Assume that the other stars of the system exert negligible gravitational force on Aa1.

g = ... ± ..... $N\,kg^{-1}$ **[4]**

(b) The table shows some data about the three stars of Algol.

Star	Luminosity of star / $L_{\odot}$	Surface temperature of star / K
Aa1	182	13000
Aa2	6.92	4500
Aa3	10.0	7500

The luminosity of each star is in terms of the solar luminosity $L_{\odot}$.

(i) Define the **luminosity** of a star.

.....

..... **[1]**

(ii) Use Stefan's law to determine the ratio $\frac{\text{radius of star Aa2}}{\text{radius of star Aa3}}$.

ratio = ... **[2]**

(iii) Use Wien's displacement law to explain which star would have the **longest** wavelength at the peak intensity of the emitted electromagnetic radiation.

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..... **[2]**

(iv) Suggest how an astronomer using just an optical telescope can deduce that the three stars of Algol have different surface temperatures.

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..... **[1]**

(v) The light from each star passing through a diffraction grating shows an absorption line spectrum.

Explain how a specific absorption line is produced in this type of spectrum in terms of **photons** and **electrons**.

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..... **[3]**

(c) The Aa1 star could evolve into a black hole.

State **two** ways in which the black hole would differ from the Aa1 star.

1. .....

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2. .....

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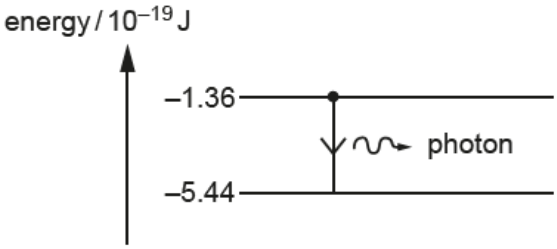
[2]

4. Nov/2020/Paper_H556_01/No.6

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]**

5. Nov/2020/Paper_H556_01/No.7

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 $2.4 \times 10^{-21}\ s^{-1}$

B $2.4 \times 10^{-18}\ s^{-1}$

C $2.4 \times 10^{-12}\ s^{-1}$

D $2.4 \times 10^{21}\ s^{-1}$

Your answer ☐ **[1]**

6. Nov/2020/Paper_H556_01/No.9

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]**

7. Nov/2020/Paper_H556_01/No.11

In astronomy, distance can be measured in different units.

Which one of the following distances is the **largest**?

A 4.22×10^{16} m

B 1.91 pc

C 3.42 ly

D 593 AU

Your answer ☐ **[1]**

(a) Our Sun will eventually become a red giant.

Describe and explain the next stages of evolution of our Sun.

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..... **[4]**

(b) Rigel is a blue giant star in the constellation of Orion.
The table below shows some data about Rigel and about our Sun.

	Rigel	**Sun**
Surface temperature / K		5.8×10^3
Luminosity / W	4.62×10^{31}	3.85×10^{26}
Wavelength of emitted light at peak intensity / nm	240	500

(i) Show that the surface temperature of Rigel is 12 000 K.

[2]

(ii) Calculate the radius of Rigel.

radius = ... m **[2]**

(c) An astronomer claims to have discovered a white dwarf with a mass twice that of our Sun.

Suggest why this claim must be incorrect.

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..... **[1]**

8. Nov/2020/Paper_H556_03/No.3

This question is about the Sun and its radiation.

(a) **(i)** Use the data below to show that the luminosity of the Sun is about 4×10^{26} W.

- radius of Sun = 7.0×10^{8} m
- surface temperature of Sun = 5800 K

[1]

(ii) Sirius, the brightest star in the night sky, has a luminosity 25 times greater than that of the Sun. It has diameter 1.7 times greater than that of the Sun.

Calculate the surface temperature T of Sirius.

T = ... K **[3]**

***(b)** A student attends a lecture about the Sun and makes the following notes.

1. The Sun loses more than 4×10^9 kg of its mass every second to maintain its luminosity.
2. Treating hydrogen nuclei (protons) as an ideal gas, a temperature of 10^{10} K provides a kinetic energy of about 1 MeV, which is necessary for fusion.
3. However, the Sun's core temperature is only 10^7 K, so the chance of protons fusing on collision is very small. This explains why the Sun has such a long lifetime.

Explain the principles of physics which are involved in each of the three points.
You should include relevant formulae, but no numbers or calculations are required.

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