1. Nov/2023/Paper_9702/41/No.3(b, c, d)

The product pV for an ideal gas is given by

$$pV = \frac{1}{3}Nm\langle c^2\rangle$$

where p is the pressure of the gas and V is the volume of the gas.

(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 $9300\,\text{m s}^{-1}$.

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 $2.52 \times 10^{-8}\,\text{W m}^{-2}$ when observed at a distance of $4.16 \times 10^{16}\,\text{m}$ 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]

(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]

3. June/2023/Paper_9702/41/No.10

(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]

4. March/2023/Paper_9702/42/No.10

(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]