1. The figure below shows the evolution of a star similar to the Sun on a Hertzsprung-Russell (HR) diagram.
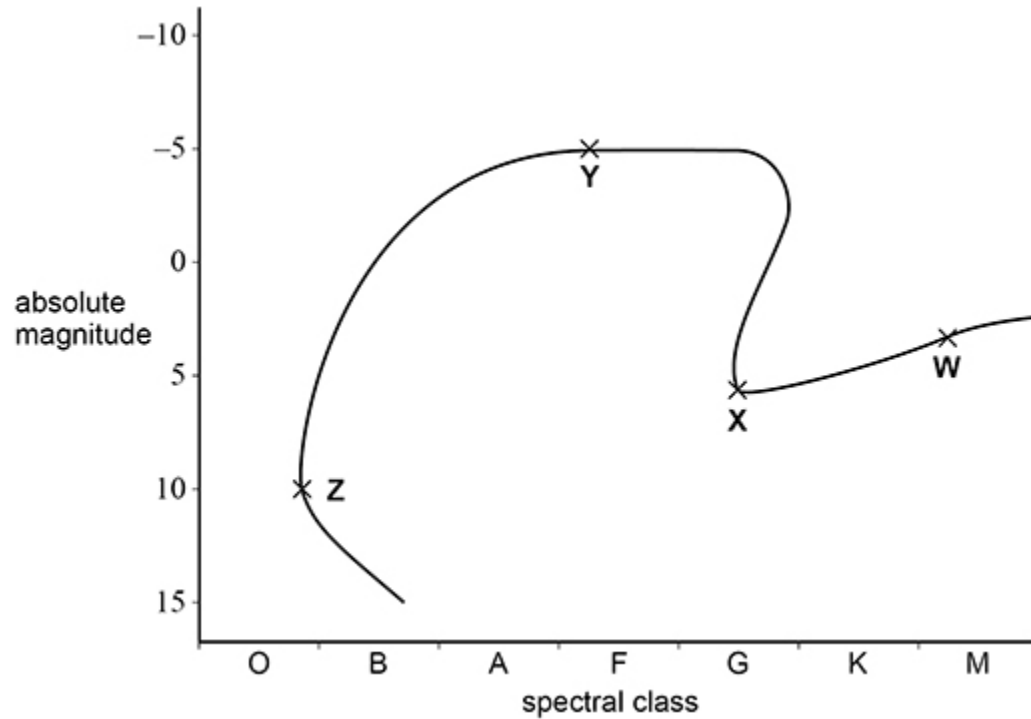

(a) State the evolutionary stage of the star at each of the points **W**, **X**, **Y** and **Z**.

W _____

X _____

Y _____

Z _____

(3)

Theta Carinae is a star with a radius five times that of the Sun. It has a surface temperature of 31 000 K.

(b) Annotate the figure above with a **T** to show the position of Theta Carinae.

(1)

An astronomer suggests that an Earth-sized planet orbits Theta Carinae.

(c)   Explain **one** difficulty with using the transit method to detect this planet.

_____

_____

_____

_____

_____

_____

(2)

(d)   The astronomer suggests that the Earth-sized planet receives a similar amount of power from Theta Carinae as the Earth does from the Sun.

The average power output of the Sun is 3.8×10^{26} W.

Determine the orbital radius of the Earth-sized planet orbiting Theta Carinae.

orbital radius = _____ m

(5)

(Total 11 marks)

2.   The table summarises some information about four stars in the constellation Cassiopeia.

Name	Colour	Apparent magnitude	Distance / ly
Caph	white	2.3	55
Ruchbah	blue/white	2.7	99
Schedar	orange	2.2	228
Tsih	blue	2.2	610

(a)   Which star has the highest surface temperature?
      Tick (✓) **one** box.

Caph   ☐
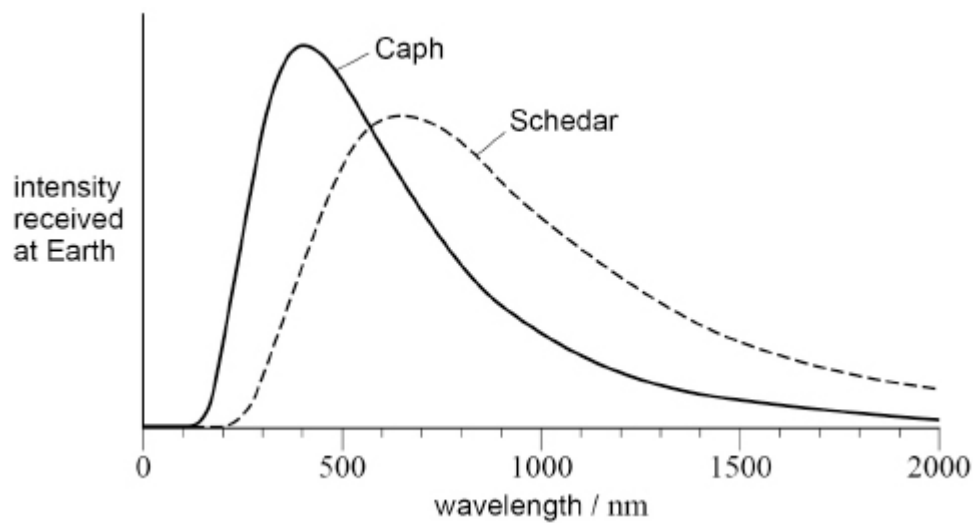
Ruchbah   ☐

Schedar   ☐

Tsih   ☐

(1)

(b)   The graph below shows the intensity received at Earth from two of the stars, plotted against wavelength.
      The effect of absorption by the Earth's atmosphere is not shown.

Discuss what information can be found from the graph about the temperature and colour of these stars.
Support your answer with suitable calculations.

_____

_____

_____

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(4)

(c)　State which star in the table above is dimmest on the absolute magnitude scale.

_____

(1)

(d)　Calculate the absolute magnitude of Schedar.

absolute magnitude = _____

(3)

(e) Tsih has a mass over 15 times the mass of the Sun.
Tsih may eventually collapse to form a black hole.

Calculate the radius of the event horizon for a black hole with a mass 15 times that of the Sun.

radius = _____ m

(2)
(Total 11 marks)

3. (a)   Which graph shows the light curve for a typical type 1a supernova?

Tick (✓) **one** box.

A

B

C

D

A ☐

B ☐

C ☐

D ☐

(1)
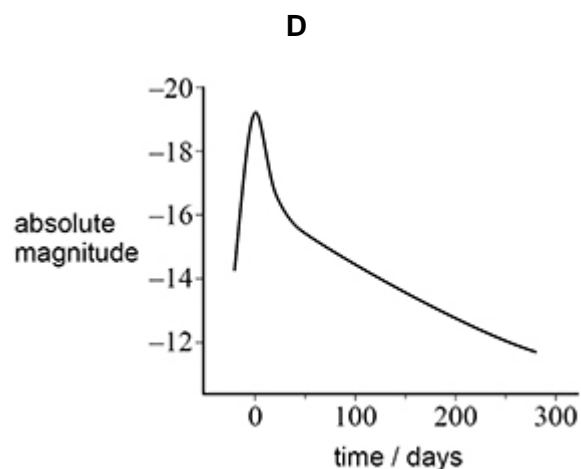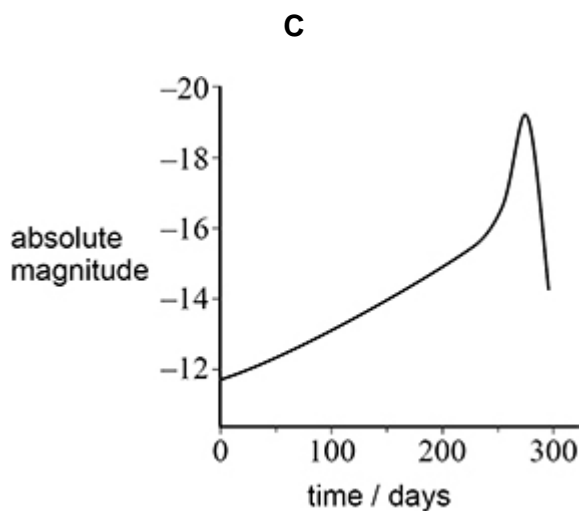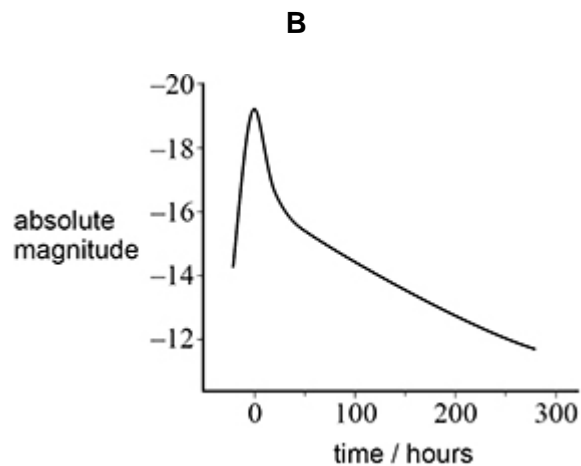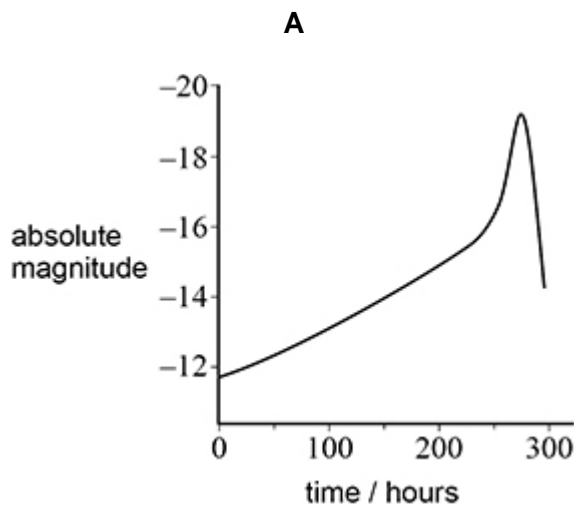
(b)   The Andromeda galaxy is approximately 7.7 × 10⁵ pc from Earth.

Deduce whether a type 1a supernova which occurred in Andromeda can be observed from Earth with the naked eye.

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(3)
(Total 4 marks)

4. Miaplacidus and Avior are two stars in the constellation Carina.
Miaplacidus is a class A star.
Avior is a class K star.

The figure below shows how the intensity of radiation arriving at the Earth varies with wavelength for **one** of these stars. Only the important features of the variation are shown.

Deduce, with reference to the figure, the identity of the star.

In your answer you should:

- explain the overall shape of the graph
- describe the processes in the star that lead to the decreases in intensity
- state the identity of the star.

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(Total 6 marks)

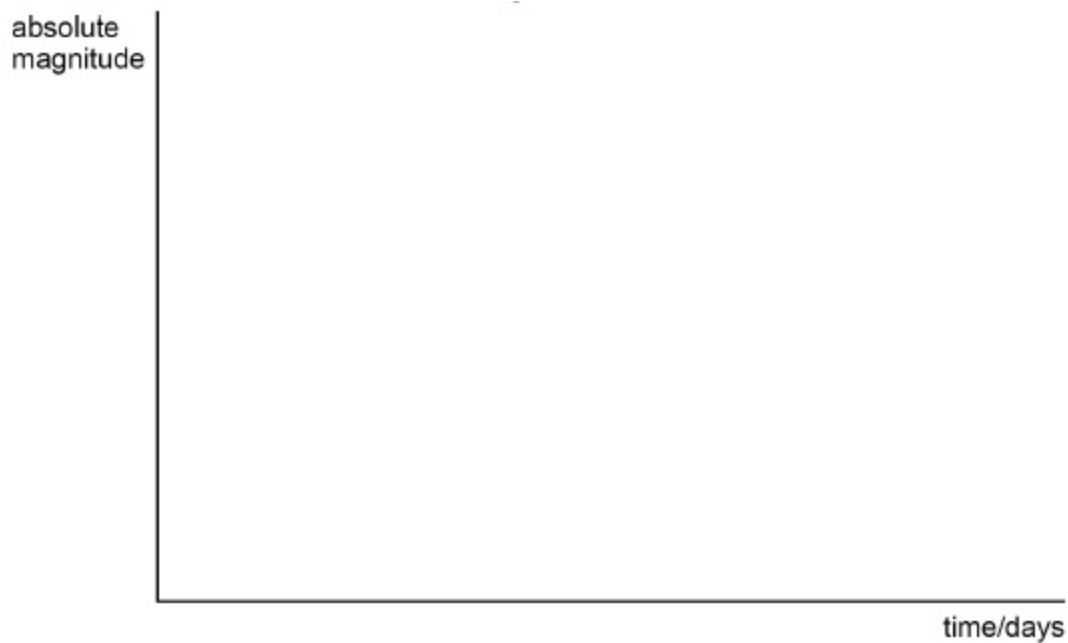**5.** (a) Sketch, on the axes, the light curve for a typical type 1a supernova.
Label the axes with suitable scales.

absolute
magnitude

time/days

(3)

(b) Type 1a supernovae can be used as standard candles.

Explain what is meant by a standard candle.

_____

_____

_____

_____

(1)

(c) Measurements of type 1a supernovae in 1999 led to a controversy concerning the behaviour of the Universe.

Describe this controversy and how the measurements led to it.

_____

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(3)
(Total 7 marks)

6. (a) Sketch, on the axes, the black-body radiation curve for a typical star.

intensity /
arbitrary units

0

0   wavelength

(2)

(b)   Explain, with reference to the SI units involved, how the curve you have drawn can be used
       to determine the black-body temperature of the star.

_____

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(3)

(c)   Two stars, 61 Cygnus A and 61 Cygnus B, can be seen very close together in the constellation Cygnus. Early astronomers were unsure whether the two stars form a binary system, or simply appear in the same line of sight.

The table shows some of the properties of the two stars.

	Temperature / K	Radius / km	Apparent magnitude
61 Cygnus A	4500	4.7×10^5	5.2
61 Cygnus B	4100	4.1×10^5	6.1

Evaluate whether the data support the suggestion that the two stars form a binary system.

In your answer you should

- compare the two stars as seen by an observer on Earth
- support your evaluation with suitable calculations.

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(6)

(d)   What is the spectral class of 61 Cygnus A?
Tick (✓) the correct box.

A ☐

F ☐

G ☐

K ☐

(1)
(Total 12 marks)

7.   The table shows some properties of the four brightest stars in the constellation Canis Minor.

Name	Apparent magnitude	Absolute magnitude	Spectral class
Gamma A	4.46	−0.50	K
Gomeisa	2.89	−0.70	B
HD 66141	4.39	−0.13	K
Procyon	0.34	2.65	F

(a)   Discuss, with reference to the Hipparcos scale, why many star maps show only two stars in the constellation Canis Minor.

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(3)

(b)   State and explain which star in the table above has the most prominent Hydrogen Balmer absorption lines.

_____

_____

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(2)

(c)   Deduce which star, Gamma A or HD 66141, has the larger diameter.

_____

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(3)

(d)   Astronomers recently used the radial velocity method to discover an exoplanet orbiting HD 66141.

Describe the main features of the radial velocity method in the detection of planets.

_____

_____

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(2)

(e)   Calculate the distance from the Earth to Procyon.
       Give an appropriate unit for your answer.

distance = _____ unit _____

(3)

(Total 13 marks)

8.   Type 1a supernovae can be used as standard candles.

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

_____

_____

(1)

(b)   Sketch on the axes below the light curve for a type 1a supernova.
       Annotate your graph with suitable scales and a unit for time.

absolute
magnitude

time /

(3)

(c)   Measurements of type 1a supernovae are used to find a value for the Hubble constant.

The distance from Earth is known for many type 1a supernovae.

Describe how these values of distance are used, with other data, to find the Hubble constant.

Your answer should include:

- the other data needed and how these data are used
- the graph plotted, including appropriate units for the axes
- how the Hubble constant is obtained and any limitations on the result.

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(6)
(Total 10 marks)

9. The table gives data about the supergiant star Melnick 34 and the Sun.

Name	Radius / m	Surface temperature / K
Melnick 34	1.4×10^{10}	53 000
Sun	7.0×10^8	5 700

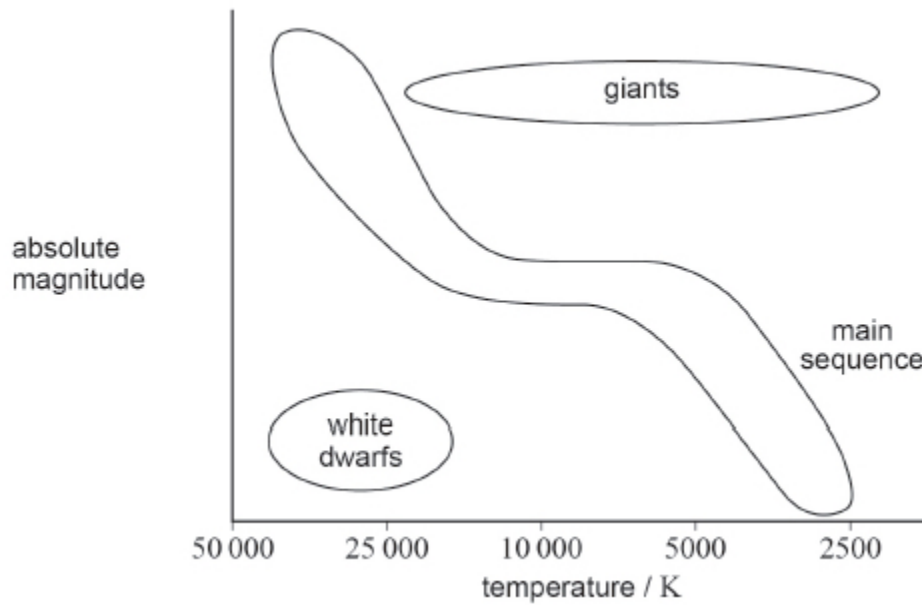(a)   Calculate $\dfrac{\text{power output of Melnick 34}}{\text{power output of the Sun}}$.

answer = _____

(2)

(b)   Discuss why the evolution of a supergiant star in the local part of our galaxy could be dangerous for life on Earth.

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(2)
(Total 4 marks)

10. Below is a Hertzsprung-Russell (HR) diagram.

(a)   Label the absolute magnitude axis with a suitable scale.

(1)

(b)   Label with an **S** the position of the Sun on the HR diagram.

(2)

(c)   Draw a line on the HR diagram to show the evolution of a star similar to the Sun from formation to white dwarf.

(2)

(d)   Label with a **P** the position on the HR diagram of a star much redder, and with a greater power output, than the Sun.

(1)

(e)   A star much more massive than the Sun may become a supernova and then a black hole.

Discuss whether supernovae and black holes can be placed on the HR diagram in.

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(3)

(Total 9 marks)

11.   (a)   Describe the links between galaxies, black holes and quasars.

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(2)

(b)   At a distance of 5.81 × 10^8 light year, Markarian-231 is the closest known quasar to the Earth. The red shift z of Markarian-231 is 0.0415

Use these data to estimate an age, in seconds, of the Universe.

age = _____ s

(4)

(c)   A typical quasar is believed to be approximately the size of the solar system, with a power output similar to that of a thousand galaxies.

Estimate, with reference to the inverse-square law, how much further the most distant visible quasar is likely to be compared to the most distant visible galaxy.

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(3)
(Total 9 marks)

12.   The table summarises some of the properties of four stars in the constellation Hercules.

Star	Distance/pc	Spectral class	Apparent magnitude
Kornephoros	43	G	2.8
Rasalgethi	110	M	3.0
Rutilicus	11	G	2.8
Sarin	23	A	3.1

(a)   Define the parsec. You may use a diagram as part of your answer.

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_____

(2)

(b)   Deduce which star is larger, Kornephoros or Rutilicus.

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(3)

(c)   One of the four stars has the peak in its black-body radiation curve at a wavelength of 1.0 μm.

Calculate the corresponding temperature for this curve.

temperature = _____ K

(2)

(d)   Explain which star produced the black-body radiation curve described in question (c).

_____

_____

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(2)

(e)   Which star has the brightest absolute magnitude?

Tick (✓) the correct box.

Kornephoros ☐

Rasalgethi ☐

Rutilicus ☐

Sarin ☐

(1)

(f)   Determine the absolute magnitude of Sarin.

absolute magnitude = _____

(3)

(Total 13 marks)