

APOLLO

Fusion and stars

HL

Physics

First assessment 2025

16 questions | questions

- 40.** A star has a parallax angle of 1×10^{-2} arc-second at the orbit of the Earth.

What is the distance from the Sun to the star?

- A. 0.01 pc
 - B. 0.02 pc
 - C. 50 pc
 - D. 100 pc
-

- 40.** Stars X and Y have the same surface temperature. Star X has a radius R and is a distance d from Earth. The distance of star Y from Earth is $\frac{d}{2}$. The apparent brightness of Y is double that of X.

What is the radius of star Y?

- A. $\frac{R}{2}$
 - B. $\frac{\sqrt{2}}{2} R$
 - C. R
 - D. $2R$
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11. Star X has a surface temperature T , luminosity L and radius R .

The luminosity of star Y is $4L$ and the surface temperature is $2T$.

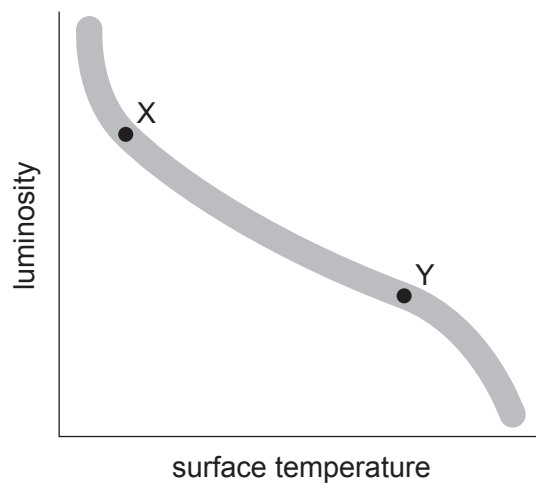
What is the radius of star Y?

- A. $\frac{R}{2}$
- B. $\frac{R}{\sqrt{2}}$
- C. $2R$
- D. $4R$

38. Which of the following temperature and density conditions are necessary for fusion to occur in a star?

	Temperature of the star	Density of the star
A.	High	High
B.	High	Low
C.	Low	High
D.	Low	Low

39. The HR diagram shows two stars, X and Y.



Three statements are made about star X and star Y.

- I. Star X is hotter than star Y.
- II. Star X has a larger radius than star Y.
- III. Star X is more luminous than star Y.

Which of the statements are correct?

- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III

40. X is a star of luminosity L and apparent brightness b . Y is a star of luminosity L and apparent brightness $2b$.

As viewed from Earth, what is $\frac{\text{parallax angle subtended by X}}{\text{parallax angle subtended by Y}}$?

- A. $\frac{1}{\sqrt{2}}$
- B. $\frac{1}{2}$
- C. $\sqrt{2}$
- D. 2
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7. The following data are available for the Sun when it entered the main sequence.

Mass = 2.0×10^{30} kg

Radius = $7.0 \times 10^8 \text{ m}$

Surface temperature = 5800 K

Core temperature = 1.5×10^7 K

Core density = $1.6 \times 10^5 \text{ kg m}^{-3}$

- (a) (i) State and explain which of the above features make nuclear fusion in the Sun possible.

[3]

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- (ii) Outline how the Sun maintains its equilibrium state.

[2]

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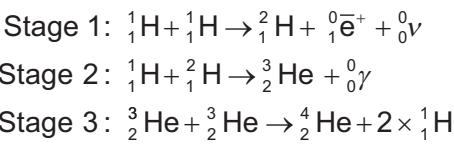
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(Question 7 continued)

(b) The following sequence of nuclear fusion reactions takes place in the Sun.



The nuclear mass of ${}_1^1\text{H}$ is 1.007276 u and that of ${}_1^2\text{H}$ is 2.013550 u. Estimate the energy released in stage 1 of these reactions.

[2]

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(Question 7 continued)

(c) The Sun will leave the main sequence when it has converted 10 % of its hydrogen mass into helium. The **total** energy released in the reactions in (b) is 4.3×10^{12} J. The current luminosity of the Sun is 3.8×10^{26} W. When the Sun entered the main sequence its hydrogen mass was 1.5×10^{30} kg.

(i) Show that the Sun will stay on the main sequence for about 8×10^9 years. [3]

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(ii) State **one** assumption that was made in getting the answer to (c)(i). [1]

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(iii) Estimate the total mass lost by the Sun in this time. [2]

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(d) The surface temperature of the Sun is 5800 K. Determine the peak wavelength in the Sun's spectrum. [2]

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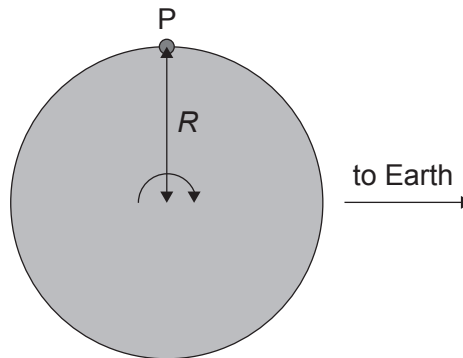
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(Question 7 continued)

- (e) The Sun rotates about its axis. P is a point on the Sun's equator.



A particular spectral line of hydrogen from a laboratory source has wavelength 656.2797 nm. The same spectral line emitted from P has wavelength 656.2753 nm when measured on Earth.

- (i) Explain this observation.

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- (ii) Calculate the period of revolution of the Sun.

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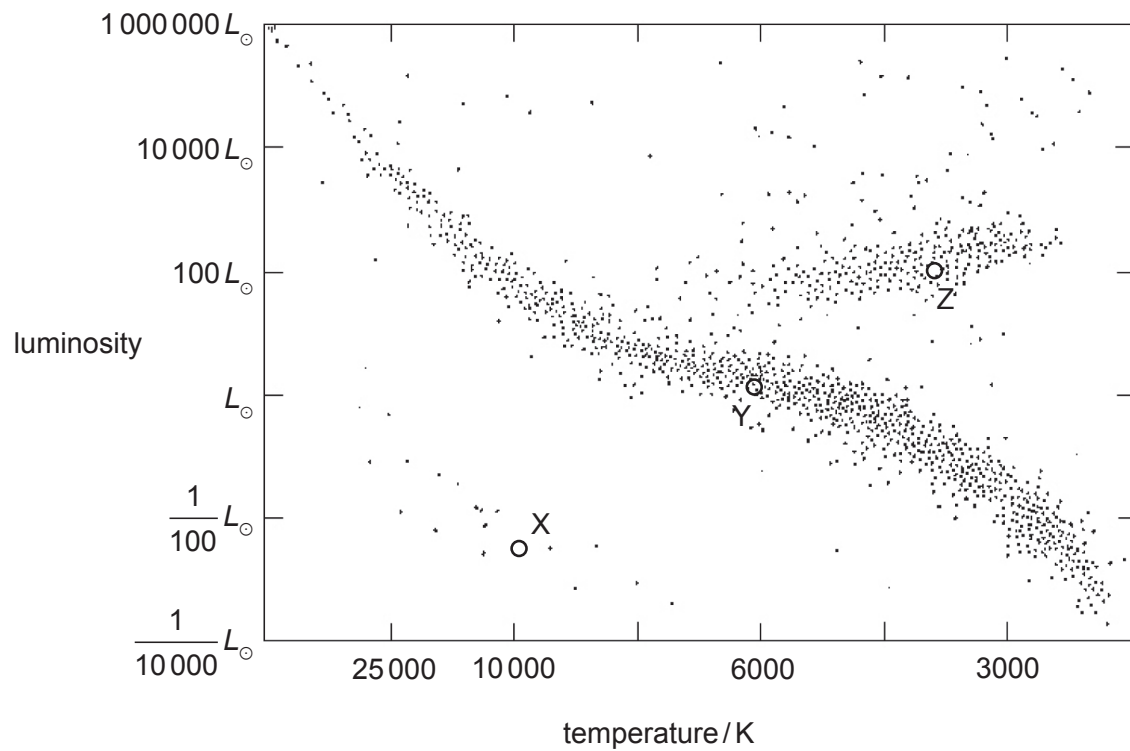


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39. The Hertzsprung–Russell diagram shows three stars X, Y and Z.

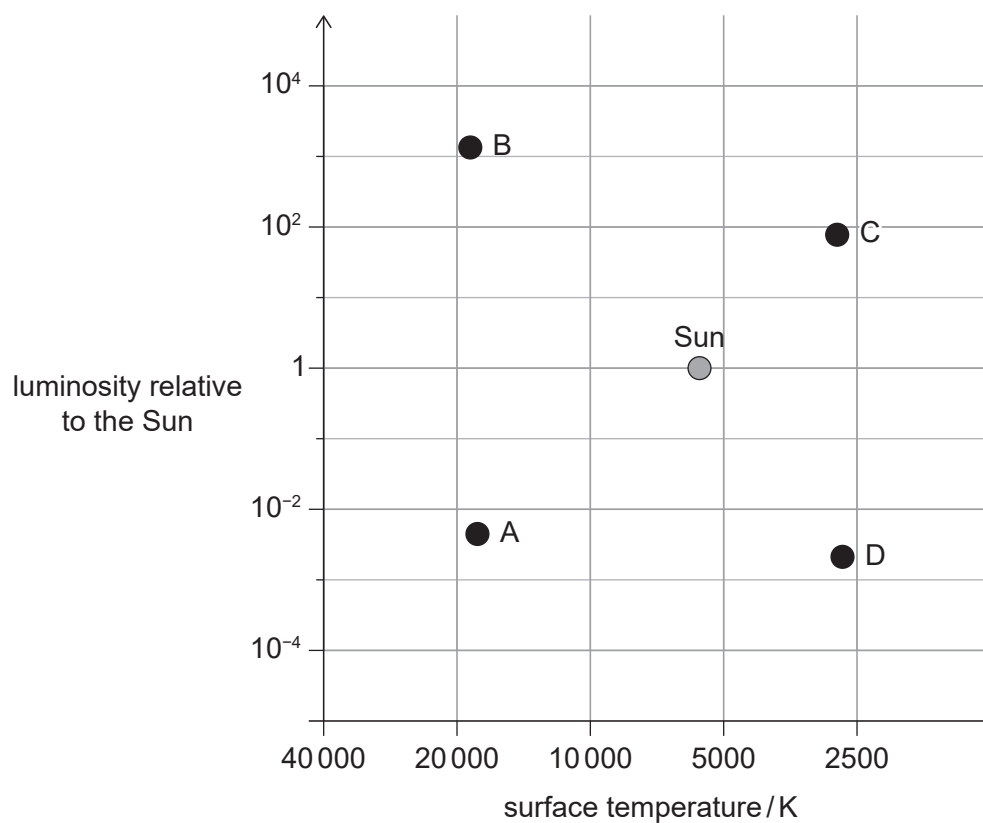


Which of the following lists the stars in the order of their evolutionary stage?

- A. X, Y, Z
- B. Z, Y, X
- C. Y, X, Z
- D. Y, Z, X

- 40.** The stellar parallax method involves a measurement of...
- A. the peak wavelength of radiation from a star.
 - B. the frequency shift of the lines in a stellar spectrum.
 - C. the position of a star in the sky at different times of year.
 - D. the intensity of radiation from a star at different wavelengths.
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39. The Sun and positions of four stars A, B, C and D are plotted on the grid of a Hertzsprung–Russell (HR) diagram. Which star is a white dwarf?



40. A star is found to have a parallax angle of 0.25 arc-seconds. What is the distance to the star in light years?

- A. 4.0
 - B. 13
 - C. 6.0×10^{11}
 - D. 38×10^{15}
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References:

7. Dorling Kindersley, 2010. *Illustration of ice skater starting to spin*. [image online] Available at: <https://www.gettyimages.co.uk/detail/illustration/illustration-of-ice-skater-starting-to-spin-royalty-free-illustration/96168836?phrase=ice+skater+spinning&searchscope=image%2Cfilm&adppopup=true> [Accessed 11 December 2024]. Source adapted.

2. A student investigates whether the Stefan–Boltzmann law, $L = 4\pi\sigma R^2T^4$, applies to stars.

L = luminosity of the star, in W

σ = Stefan–Boltzmann constant

R = radius of the star, in m

T = surface temperature of the star, in K

To verify the law, they obtain values from databases and manipulate the data as shown.

Star	L	R	T	$\frac{L}{R^2}$	$\log(\frac{L}{R^2})$	$\log(T)$
10 Lacertae	3.92×10^{31}	5.75×10^9	3.62×10^4	1.19×10^{12}	12.1	4.56
σ -Orionis A	1.60×10^{31}	3.90×10^9	3.49×10^4	1.05×10^{12}	12.0	4.54
σ -Orionis B	6.08×10^{30}	3.48×10^9	2.91×10^4	5.02×10^{11}	11.7	4.46
Polaris B	1.50×10^{27}	9.60×10^8	6.90×10^3		9.21	
α -Centauri A	5.77×10^{26}	8.49×10^8	5.79×10^3	8.00×10^8	8.90	3.76
α -Centauri B	1.92×10^{26}	5.97×10^8	5.26×10^3	5.39×10^8	8.73	3.72
ε -Indi	8.08×10^{25}	4.95×10^8	4.65×10^3	3.30×10^8	8.52	3.67
Sun	3.85×10^{26}	6.96×10^8	5.78×10^3	7.95×10^8	8.90	3.76

- (a) Complete the table with the missing values for Polaris B.

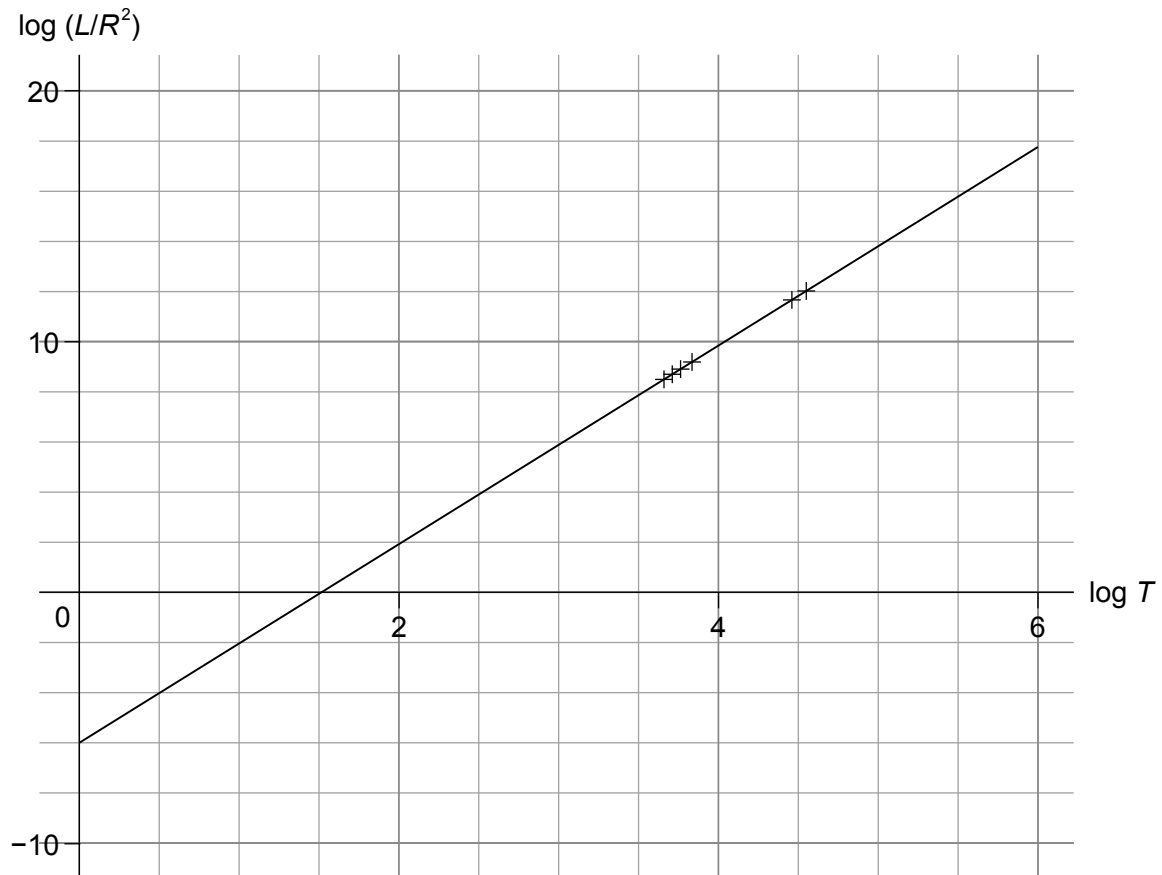
[2]

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(Question 2 continued)

The student plots the variation with $\log T$ of $\log \left(\frac{L}{R^2} \right)$ and draws the line of best fit.



The student uses a GDC (graphical display calculator) to determine the equation of the line of best fit as $y = 3.99x - 6.15$.

- (b) Explain how the gradient of the line of best fit relates to the Stefan–Boltzmann law. [2]

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(Question 2 continued)

(c) Calculate the Stefan–Boltzmann constant obtained in this investigation. [2]

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(d) Outline a conclusion for the investigation. [1]

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(e) Suggest a possible improvement of the investigation, related to the range of the surface temperatures of the stars selected. [1]

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- 14.** Star X has a luminosity L and an apparent brightness b . Star X is at a distance d from Earth.

Star Y has the same apparent brightness as X but is four times more luminous.

What is the distance of Star Y from Earth?

A. $4d$

B. $2d$

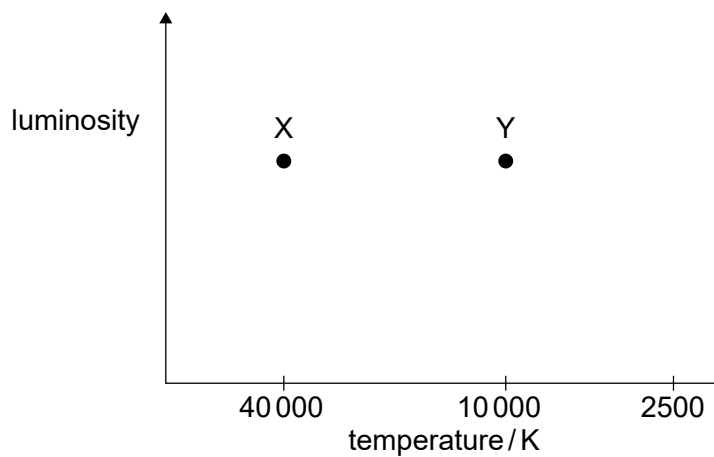
C. $\frac{d}{2}$

D. $\frac{d}{4}$

33. What is the sequence for the evolution of a main sequence star of about 2 solar masses?

- A. Red super giant → supernova → neutron star
- B. Red giant → planetary nebula → white dwarf
- C. Red giant → supernova → white dwarf
- D. Red super giant → planetary nebula → neutron star

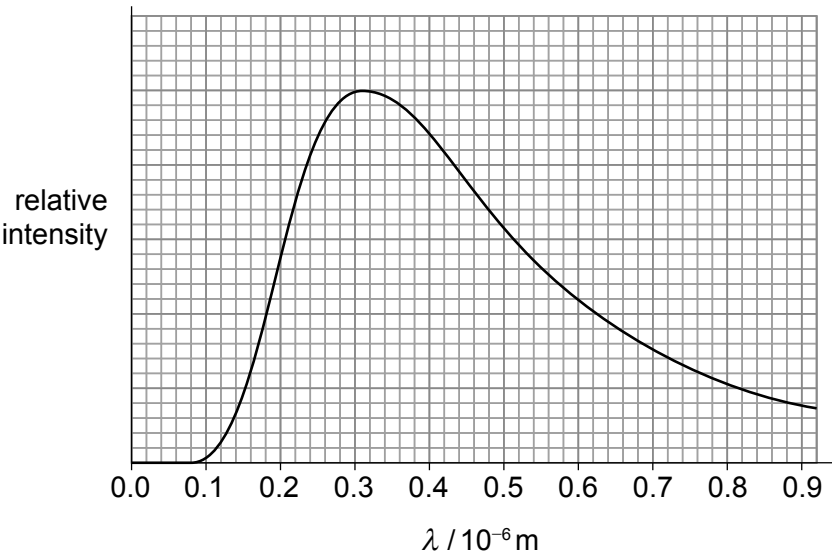
37. The Hertzsprung–Russell diagram shows two stars, X and Y.



What is $\frac{\text{radius of X}}{\text{radius of Y}}$?

- A. $\frac{1}{16}$
- B. $\frac{1}{4}$
- C. 4
- D. 16

7. The star δ Vel A is a main sequence star that has a black-body spectrum as shown.



(a) Show that the surface temperature of δ Vel A is about 9000 K. [1]

(b) The apparent brightness of δ Vel A is $2.2 \times 10^{-9} \text{ W m}^{-2}$ and it is $6.2 \times 10^{14} \text{ km}$ from Earth.
 Estimate the radius of δ Vel A. [3]

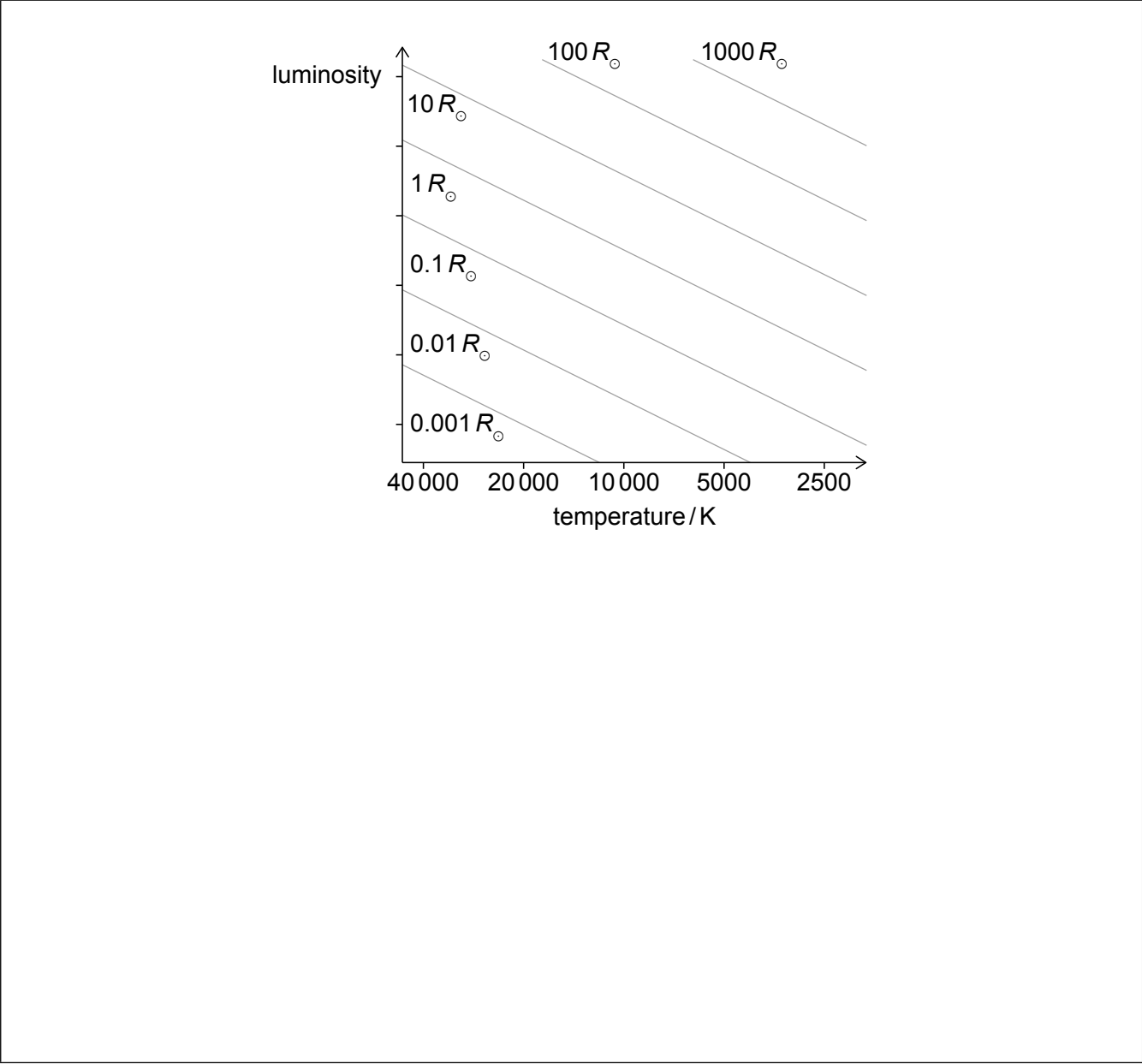
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(Question 7 continued)

(c) The radius of the Sun, $R_{\odot}$, is 7.0×10^5 km.

Sketch, on the Hertzsprung-Russell diagram, the position of δ Vel A. [2]



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