# E3 STELLAR DISTANCES
# E4 COSMOLOGY *HW/Study Packet*

| SL/HL | |
|---|---|
| Required:<br>READ Hamper Ch 10 | Supplemental:<br>Tsokos, pp 506-520 |

**REMEMBER TO….**

- ✓ *Work through all of the 'example problems' in the texts as you are reading them*
- ✓ *Refer to the **IB Physics Guide** for details on what you need to know about this topic*
- ✓ *Refer to the **Study Guides** for suggested exercises to do each night*
- ✓ *First try to do these problems using only what is provided to you from the **IB Data Booklet***
- ✓ *Refer to the solutions/key ONLY after you have attempted the problems to the best of your ability*

**UNIT OUTLINE**

**I. STELLAR DISTANCES**
- A. THE PARALLAX METHOD
- B. ABSOLUTE AND APPARENT MAGNITUDES
- C. SPECTROSCOPIC PARALLAX
- D. CEPHEID VARIABLES

**II. COSMOLOGY**
- A. OLBERS' PARADOX
- B. THE BIG BANG MODEL
- C. THE DEVELOPMENT OF THE UNIVERSE

**FROM THE IB DATA BOOKLET**

$$d(\text{parsec}) = \frac{1}{p(\text{arc-second})} \qquad m - M = 5\lg\left(\frac{d}{10}\right)$$

**WHAT YOU SHOULD BE ABLE TO DO AT THE END OF THIS TOPIC**

- □ Describe the methods of parallax, spectroscopic parallax, and cepheids for determining astronomical distances to stars
- □ Define parsec, apparent brightness, and apparent/absolute magnitude
- □ Use the magnitude-distance formula
- □ Describe Olbers' paradox in Newtonian cosmology and how it is resolved
- □ Describe the main features of the Big Bang and the expansion of the universe
- □ Understand the significance of the cosmic background radiation
- □ State the meanings of the terms 'open' and 'closed' universe
- □ Outline the theoretical possibilities for the evolution of the universe
- □ State the meaning and significance of the term 'critical density'
- □ Appreciate the international nature of astrophysics research and evaluate arguments related to investing resources into astrophysics research
- □ Appreciate the importance of various forms of dark matter

**HOMEWORK PROBLEMS:**

**1.** The star Wolf 359 has a parallax angle of 0.419 arcseconds.

a) Describe in detail, with the aid of a diagram if necessary, how this parallax angle is measured.

b) Calculate the distance in light-years from Earth to Wolf 359. **[7.78 ly]**

c) The ratio $\frac{\text{apparent brightness of Wolf 359}}{\text{apparent brightness of the Sun}}$ is $3.7 \times 10^{-15}$. Determine the ratio $\frac{\text{luminosity of Wolf 359}}{\text{luminosity of the Sun}}$

**[$8.9 \times 10^{-4}$]**

d) The surface temperature of Wolf 359 is 2800 K and its luminosity is $3.5 \times 10^{23}$ W. Calculate the radius of Wolf 359. **[$8.9 \times 10^{7}$ m]**

e) Suggest why Wolf 359 is neither a white dwarf nor a red giant.

**2.** Betelgeuse and Rigel are two super giants in the constellation of Orion.

a) The star Betelgeuse has a parallax of 0.0077 arc second. Calculate the distance between Betelgeuse and Earth. **[130 pc]**

b) State why the Hipparcos satellite (which orbits Earth) is able to measure stellar parallaxes for stars at considerably greater distances than 130 pc.

The table below gives some information about the types and magnitudes of Betelgeuse and Rigel.

| Star | Type | Apparent magnitude | Colour | Apparent brightness |
|---|---|---|---|---|
| Betelgeuse | M | −0.04 | | $2.0 \times 10^{-7}$ W m$^{-2}$ |
| Rigel | B | 0.12 | | $3.4 \times 10^{-8}$ W m$^{-2}$ |

c) Complete the above table for the colours of the stars. **[red, blue]**

d) State why Betelgeuse has a lower apparent magnitude than Rigel.

e) Given that the distance of Betelgeuse from Earth is 130 pc, calculate the luminosity of Betelgeuse. **[$4 \times 10^{31}$ W]**

f) The luminosity of Rigel is $2.3 \times 10^{31}$ W. Without any further calculation, explain whether Rigel is closer or further than Betelgeuse from Earth.

**3.** The table gives information on three stars, Achernar, EG 129 and Mira.

| | Absolute magnitude | Apparent magnitude | Spectral class |
|---|---|---|---|
| Achernar | –3.0 | +0.50 | B |
| EG 129 | +13.0 | +14.0 | B |
| Mira | –3.0 | +5.0 | M |

a) State which **one** of the three stars appears brightest from Earth. **[Achernar]**

b) Estimate the ratio $\frac{L_A}{L_E}$ where $L_A$ is the luminosity of Achernar and $L_E$ is the luminosity of EG 129.

**[$2.5 \times 10^6$]**

**c)** Determine the distance of the star Achernar from Earth. **[50 pc]**

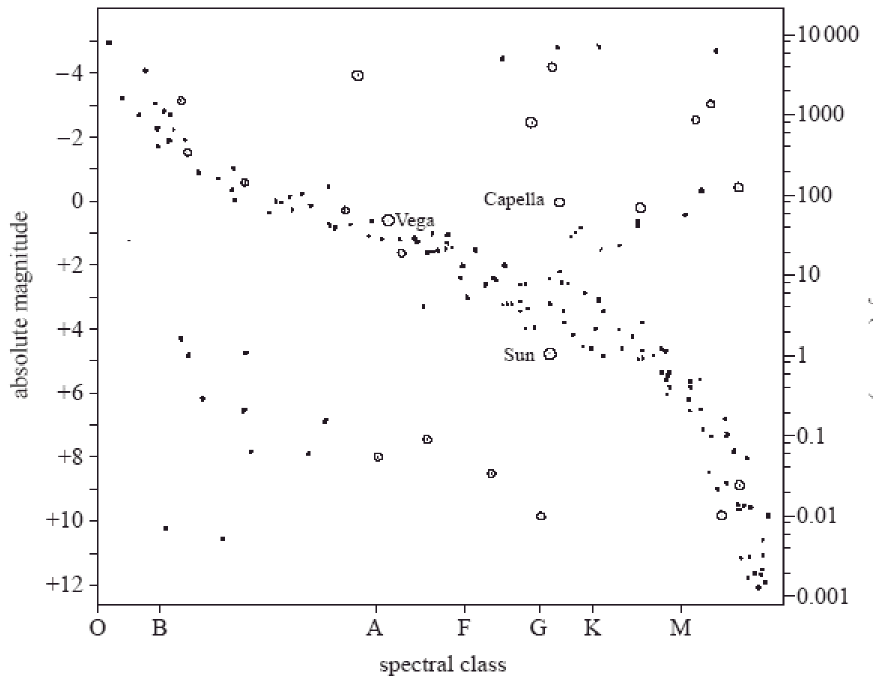
d) The surface temperature of Mira is 5 times lower than that of Achernar. Estimate the ratio $\frac{R_M}{R_A}$ where $R_M$ is the radius of Mira and $R_A$ is the radius of Achernar. **[25]**

e) State and explain which of the stars in the table is a white dwarf.

**4.** The spectroscopic parallax method can be used to measure the distance of star Vega.

a) Using the HR diagram shown, state the absolute magnitude of Vega. **[0.4-0.8]**

b) The apparent magnitude of Vega is 0.0. Determine (in parsec) the distance of Vega from Earth. **[7.6 pc]**




c) Light from Vega is absorbed by a dust cloud between Vega and Earth. Suggest the effect, if any, this will have on determining the distance of Vega from Earth.

**5.** Newton assumed that the universe is static and that the stars are uniformly distributed.

a) State **one** further assumption of the Newtonian universe.

b) Explain how Newton's assumptions led to Olbers' paradox.

**6.** Billions of years after the ‘Big Bang’, remnants of this gigantic explosion are still detectable.

a) Explain how the cosmic microwave background (CMB) radiation is consistent with the Big Bang model.

b) Calculate the temperature of the universe when the peak wavelength of the CMB was equal to the wavelength of red light ($7.0 \times 10^{-7}$ m). **[4100 K]**

**7.** a) Explain how the future of the universe may be predicted by comparing the estimated density of the universe to the critical density.

b) Explain why the existence of dark matter makes it difficult to measure the density of the universe.

**8.** The graph shows the spectrum of the cosmic microwave background radiation. The shape of the graph suggests a black body spectrum *i.e.* a spectrum to which the Wien displacement law applies.

a) Use the graph to estimate the black body temperature. **[about 2.7 K]**

b) Explain how your answer to (a) is evidence in support of the Big Bang model.