

**OXFORD CAMBRIDGE AND RSA EXAMINATIONS  
A LEVEL**

**H557/02**

**Physics B (Advancing Physics)  
Scientific literacy in physics  
Insert**

**WEDNESDAY 21 JUNE 2017: Morning  
TIME ALLOWED: 2 hours 15 minutes  
plus your additional time allowance**

**MODIFIED ENLARGED**

**INSTRUCTIONS**

**Do not send this Insert for marking; it should be retained  
in the centre or recycled.**

**Please contact OCR Copyright should you wish to re-use  
this document.**

**INFORMATION**

**This Insert contains the Advance Notice.**



## How far are the stars?

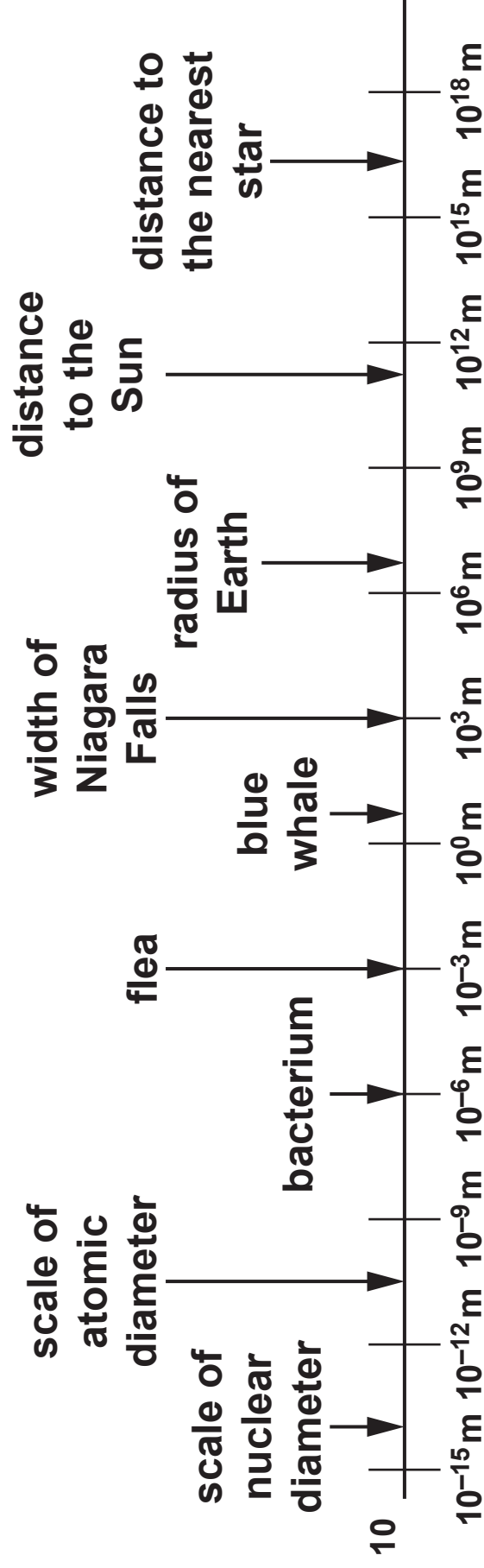
Over the past two hundred years, scientists have measured the Universe from the largest scale, that of the Universe itself, to the smallest particle. Fig. 1  
5 opposite illustrates some of the range of these measurements.

### The world of the very small – angular resolution of optical images

The limit of detail that can be identified is considered  
10 in terms of **ANGULAR RESOLUTION**: the minimum angle between objects that can be formed into separate images. Diffraction effects limit the angular resolution of all optical instruments, including the  
15 human eye which has an angular resolution of about  $0.02^\circ$ .

The story of scientific measurement is one of early approximations followed by successive improvements in techniques and instruments. For  
20 example, some early estimates of the sizes of atoms came from estimating the number of atoms in a known volume whereas estimates of the distances to stars used the (incorrect) assumption that all stars are equally bright.

FIG. 1



## 25 The distance to the nearest stars

Fig. 2 opposite shows the principle of stellar parallax. As the Earth moves around the Sun a nearby star will shift its position relative to more distant stars. If the Earth-Sun distance is known, the angular shift can lead to a value for the distance to the nearby star using simple trigonometry.

It was not until well into the 19th Century that the resolution of telescopes reached a standard where observations of parallax could be made where the uncertainties in the measurements did not swamp any possible measurement of parallax angle. In 1868, Friedrich Bessel used a refined version of the process described above to establish the distance to the star 61 Cygni. He measured the parallax angle as  $0.000\,079\,8^\circ$ , suggesting a distance of between 11 and 12 light years.

### The astronomical unit and the parsec

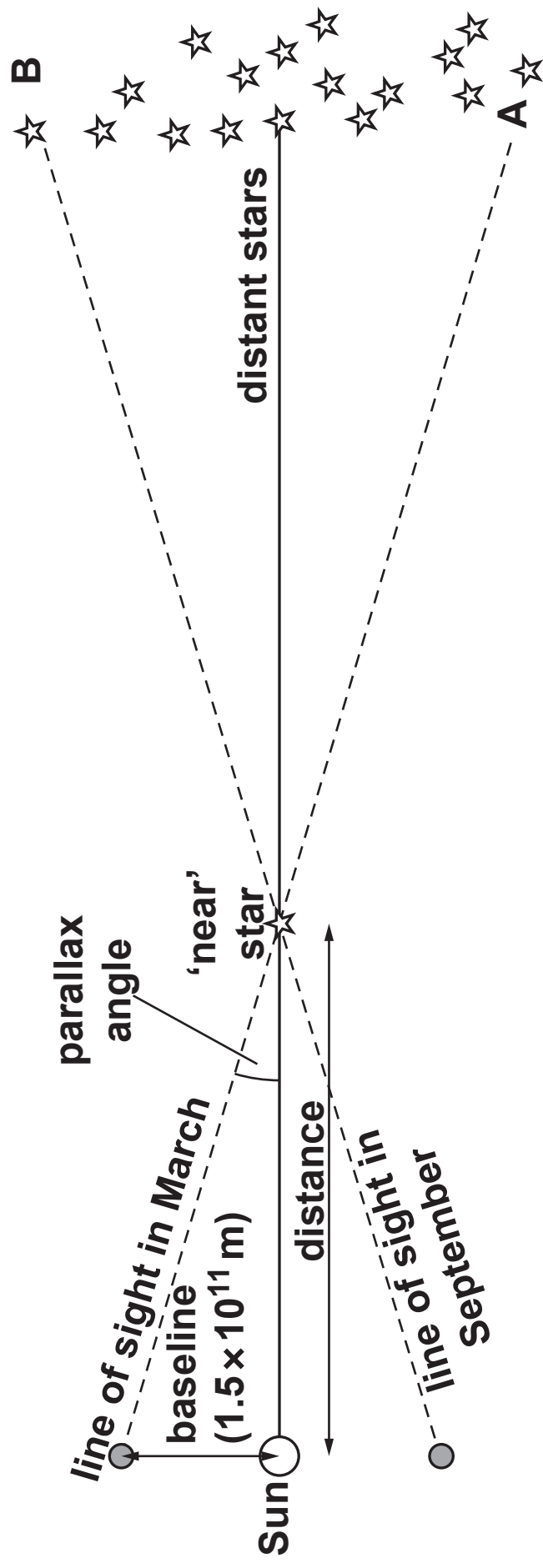
The Earth-Sun distance is known as the 'astronomical unit' (AU).

The arcsecond is  $1/3600$  of a degree. If a star gives a parallax angle of one arcsecond, the distance from Earth is defined as one parsec (parallax-second). The parsec is a measure of distance rather than time, whatever some science fiction films suggest.

For small angles the distance in parsecs is given by the equation:

$$\text{distance in parsecs} = \frac{1}{\text{parallax angle in arcseconds}}.$$

FIG. 2



## Gaia

55 The turbulent movements of the Earth's atmosphere  
produce density changes in the air through which  
the light from stars travels and limits the resolution  
of ground-based telescopes to about one-hundredth  
60 of an arcsecond. This means that the greatest  
distance that can be measured using parallax  
is about one hundred parsecs. Achieving better  
resolution requires satellite observations; beyond  
the atmosphere the Gaia satellite (launched in 2013)  
can produce images with an angular resolution of as  
65 little as 0.000 02 arc seconds.

### Spectroscopic measurement of stellar distances

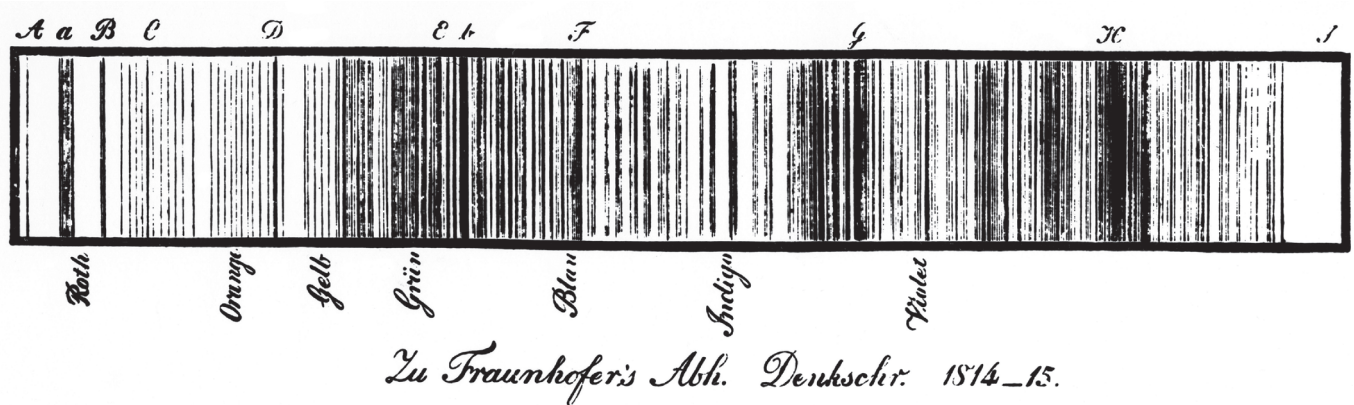
Professional astronomers measure brightness with  
a logarithmic scale called stellar magnitudes, but  
this is not appropriate here. We shall deal only with  
70 absolute brightness and apparent brightness.

Absolute brightness is the power emitted by a star  
in the visible range of the spectrum. Stars do not  
have the same absolute brightness as one another.  
However, different 'spectral classes' of stars have  
75 different ranges of brightness. Some classes of stars  
are always brighter than others. This can be useful  
in estimating distances from the apparent brightness  
of stars. If we know that a certain star belongs to  
a class that are very bright but the particular star  
80 appears to be quite dim we can conclude that it must  
be far from the Earth. The spectral class of a star can  
be determined by analysing the spectral lines in its  
spectrum.

85 When light passes through the relatively cool, gaseous upper layers of a star the atoms of the gas absorb frequencies specific to each isotope present in the layer. This produces the dark lines of an 'absorption spectrum'.

90 Fig. 3 shows an early diagram of the solar spectrum, drawn by the German spectroscopist Josef von Fraunhofer in 1814 although the explanation of the lines had to wait until the development of the quantum picture of light.

FIG. 3



- 95 The position and thickness of the spectral lines allow astronomers to identify the SPECTRAL CLASSIFICATION OF THE STAR. Once this is known, the absolute brightness of the star can be found. The distance to the star can be calculated by  
100 comparing its absolute brightness with its apparent brightness and using the inverse-square law:

apparent brightness  $\propto \frac{1}{r^2}$  where  $r$  is the distance to the star.

- Apparent brightness = absolute brightness only for a  
105 star at a distance  $r = 10$  pc, so

$$\text{Apparent brightness} = K \times \frac{\text{absolute brightness}}{r^2}$$

where the constant  $K = 100 \text{ pc}^2$  when the distance  $r$  is measured in pc.

END OF ADVANCE NOTICE ARTICLE



**BLANK PAGE**

**BLANK PAGE**

**BLANK PAGE**

## **Copyright Information**

**OCR is committed to seeking permission to reproduce all third-party content that it uses in its assessment materials. OCR has attempted to identify and contact all copyright holders whose work is used in this paper. To avoid the issue of disclosure of answer-related information to candidates, all copyright acknowledgements are reproduced in the OCR Copyright Acknowledgements Booklet. This is produced for each series of examinations and is freely available to download from our public website ([www.ocr.org.uk](http://www.ocr.org.uk)) after the live examination series.**

**If OCR has unwittingly failed to correctly acknowledge or clear any third-party content in this assessment material, OCR will be happy to correct its mistake at the earliest possible opportunity.**

**For queries or further information please contact the Copyright Team, First Floor, 9 Hills Road, Cambridge CB2 1GE.**

**OCR is part of the Cambridge Assessment Group; Cambridge Assessment is the brand name of University of Cambridge Local Examinations Syndicate (UCLES), which is itself a department of the University of Cambridge.**